The collar should be positioned so that the shearing edge of the pin groove is just below the top of the collar. It is permissible to add a 0.032-in. (approximately) steel washer between the collar and the material to bring the collar to the desired location. The washer may be positioned on the rivet head side of the material when using a flathead rivet.

Hi-Shear rivets are installed with standard bucking bars and pneumatic riveting hammers. They require the use of a special gun set that incorporates collar swaging and trimming and a discharge port through which excess collar material is discharged. A separate size set is required for each shank diameter.

Prepare holes for pin rivets with the same care as for other close tolerance rivets or bolts. At times, it may be necessary to spot-face the area under the head of the pin so that the head of the rivet can fit tightly against the material. The spot-faced area should be $\frac{1}{16}$ in. larger in diameter than the head diameter.

Pin rivets may be driven from either end. Procedures for driving a pin rivet from the collar end are:

(1) Insert the rivet in the hole.

(2) Place a bucking bar against the rivet head.

(3) Slip the collar over the protruding rivet end.

(4) Place previously selected rivet set and gun over the collar. Align the gun so that it is perpendicular to the material.

(5) Depress the trigger on the gun, applying pressure to the rivet collar. This action will cause the rivet collar to swage into the groove on the rivet end.

(6) Continue the driving action until the collar is properly formed and excess collar material is trimmed off. (See figure 5–71.)

Procedures for driving a pin rivet from the head end are:

(1) Insert the rivet in the hole.

(2) Slip the collar over the protruding end of rivet.

(3) Insert the correct size gun rivet set in a bucking bar and place the set against the collar of the rivet.

(4) Apply pressure against the rivet head with a flush rivet set and pneumatic riveting hammer.

(5) Continue applying pressure until the collar is formed in the groove and excess collar material is trimmed off.

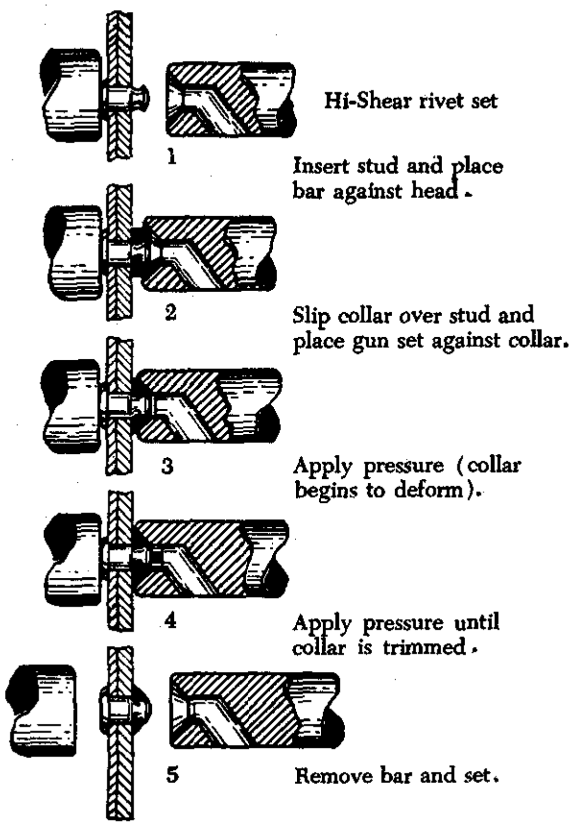


FIGURE 5–71. Using pin rivet set.

Inspection

Pin rivets should be inspected on both sides of the material. The head of the rivet should not be marred and should fit tightly against the material. Figure 5–72 illustrates acceptable and unacceptable rivets.

Removal of Pin Rivets

The conventional method of removing rivets by drilling off the head may be utilized on either end of the pin rivet (figure 5–73). Center punching is recommended prior to applying drilling pressure. In some cases alternate methods may be more desirable for particular instances.

Grind a chisel edge on a small pin punch to a blade width of $\frac{1}{8}$ in. Place this tool at right angles to the collar and drive with a hammer to split the collar down one side. Repeat the operation on the opposite side. Then, with the chisel blade, pry the collar from the rivet. Tap the rivet out of the hole.

Use a special hollow punch having one or more

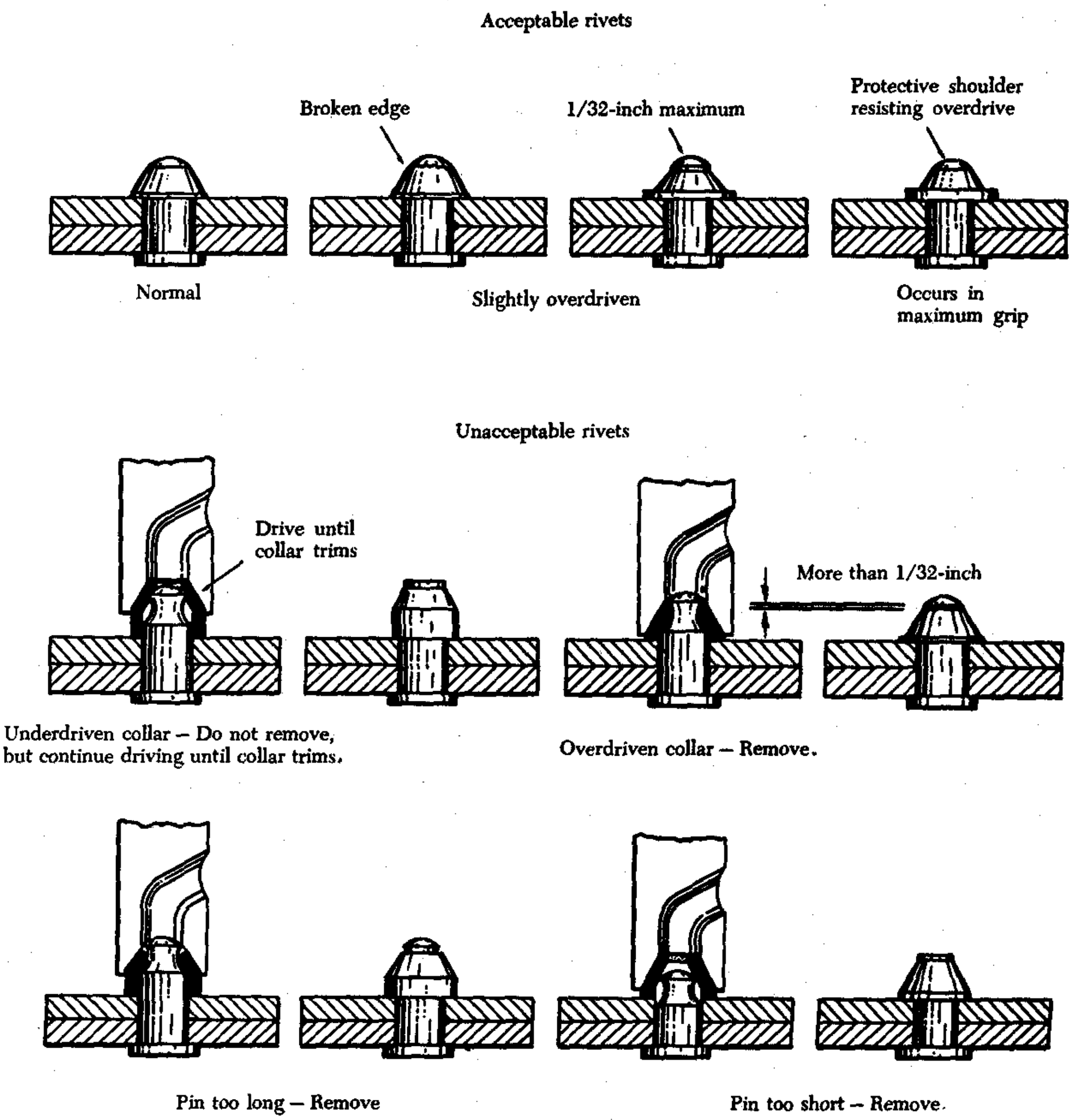


FIGURE 5-72. Pin rivet inspection.

blades placed to split the collar. Pry the collar from the groove and tap out the rivet.

Grind a pair of nippers so that cutting blades will cut the collar in two pieces, or use nippers at right angles to the rivet and cut through the small neck.

A hollow-mill collar cutter can be used in a power hand drill to cut away enough collar material to permit the rivet to be tapped out of the work.

SPECIFIC REPAIR TYPES

Before discussing any type of a specific repair that could be made on an aircraft, remember that the methods, procedures, and materials mentioned in the following paragraphs are only typical and should not be used as the authority for the repair. When repairing a damaged component or part, consult the applicable section of the manufacturer's structural repair manual for the aircraft. Normally, a similar repair will be illustrated, and the types of material, rivets, and rivet spacing and the methods and procedures to be used will be listed. Any addi-

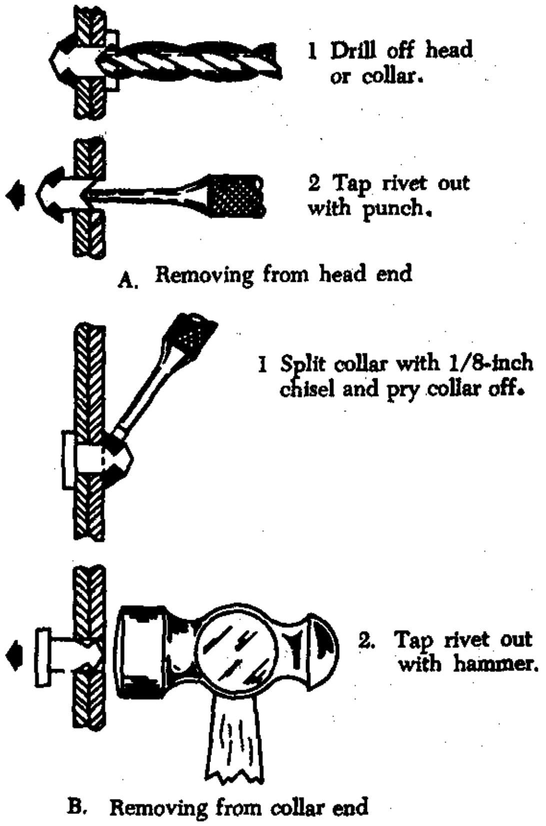


FIGURE 5-73. Removal of pin rivets.

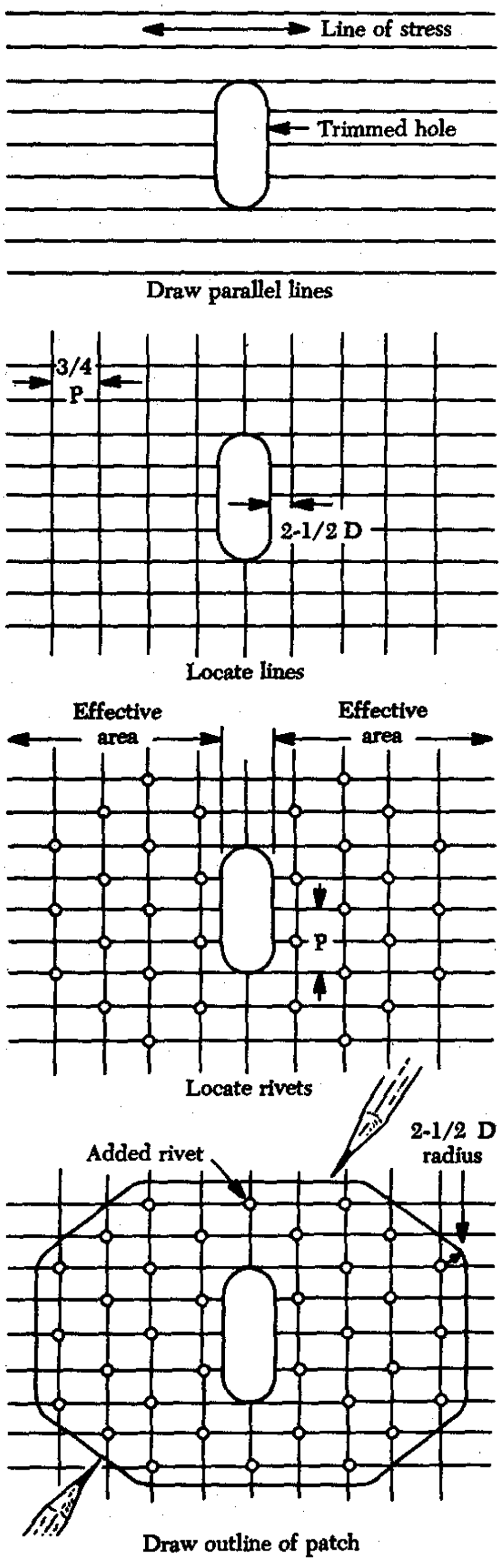


FIGURE 5-74. Elongated patch.

tional knowledge needed to make a repair will also be detailed.

If the necessary information is not found in the structural repair manual, attempt to find a similar repair or assembly installed by the manufacturer of the aircraft.

Smooth Skin Repair

Minor damage to the outside skin of an aircraft can be repaired by applying a patch to the inside of the damaged sheet. A filler plug must be installed in the hole made by the removal of the damaged skin area. It plugs the hole and forms a smooth outside surface necessary for aerodynamic smoothness of modern day aircraft.

The size and shape of the patch is determined in general by the number of rivets required in the repair. If not otherwise specified, calculate the required number of rivets by using the rivet formula. Make the patch plate of the same material as the original skin and of the same thickness or of the next greater thickness.

Elongated Octagonal Patch

Whenever possible, use an elongated octagonal patch for repairing the smooth skin. This type of patch provides a good concentration of rivets within the critical stress area, eliminates dangerous stress concentrations, and is very simple to lay out. This patch may vary in length according to the condition of the repair.

Follow the steps shown in the paper layout of this patch (figure 5–74). First, draw the outline of the trimmed-out damage. Then, using a spacing of three to four diameters of the rivet to be used, draw lines running parallel to the line of stress. Locate the lines for perpendicular rows two and one-half rivet diameters from each side of the cutout, and space the remaining lines three-fourths of the rivet pitch apart.

Locate the rivet spots on alternate lines perpendicular to the stress lines to produce a stagger between the rows and to establish a distance between rivets (in the same row) of about six to eight rivet diameters. After locating the proper number of rivets on each side of the cutout, add a few more if necessary so that the rivet distribution will be uniform. At each of the eight corners, swing an arc of two and one-half rivet diameters from each corner rivet. This locates the edge of the patch. Using straight lines, connect these arcs to complete the layout.

Round Patch

Use the round patch for flush repairs of small holes in smooth sheet sections. The uniform distribution of rivets around its circumference makes it an ideal patch for places where the direction of the stress is unknown or where it is known to change frequently.

If a two-row round patch is used (figure 5–75), first draw the outline of the trimmed area on paper. Draw two circles, one with a radius equal to the radius of the trimmed area plus the edge distance, and the other with a radius ¾-in. larger. Determine the number of rivets to be used and space two-thirds of them equally along the outer row. Using any two adjacent rivet marks as centers, draw intersecting arcs; then draw a line from the point of intersection of the arcs to the center of the patch. Do the same with each of the other pairs of rivet marks. This will give half as many lines as there are rivets in the outer row. Locate rivets where these lines intersect the inner circle. Then transfer the layout to the patch material, adding regular outer

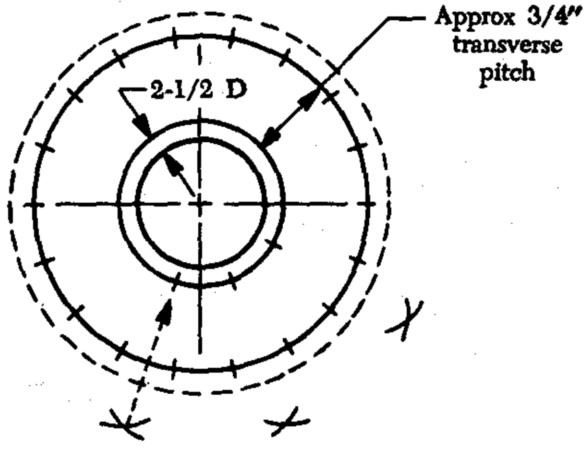


FIGURE 5–75. Layout of a two-row round patch.

edge material of two and one-half rivet diameters to the patch.

Use a three-row round patch (figure 5–76) if the total number of rivets is large enough to cause a pitch distance smaller than the minimum for a two-row patch. Draw the outline of the area on paper; then draw a circle with a radius equal to that of the trimmed area plus the edge distance. Equally space one-third of the required number of rivets in this row. Using each of these rivet locations as a center, draw arcs having a ¾-in. radius. Where they intersect, locate the second row rivets. Locate the third row in a similar manner. Then allow extra material of two and one-half rivet diameters around the outside rivet row. Transfer the layout to the patch material.

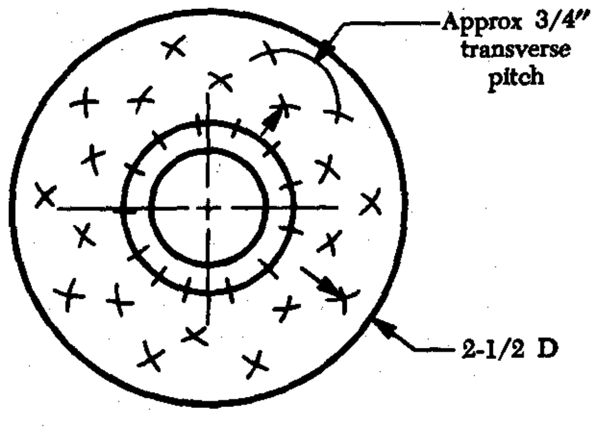


FIGURE 5–76. Layout of a three-row round patch.

After laying out and cutting the patch, remove the burrs from all edges. Chamfer the edges of all external patches to a 45° angle and turn them slightly downward so that they will fit close to the surface (figure 5–77).

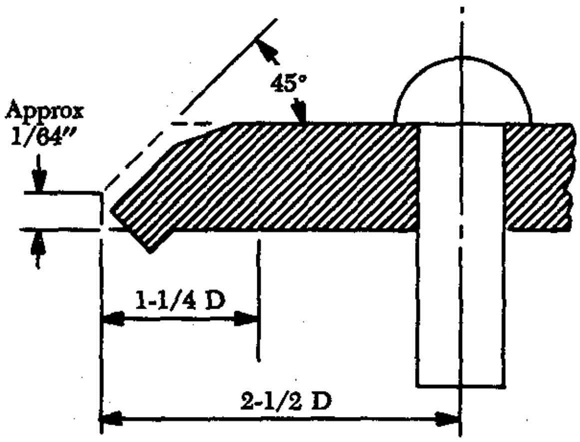


FIGURE 5–77. Chamfering and turning edge.

Panel Repair

In aircraft construction, a panel is any single sheet of metal covering. A panel section is the part of a panel between adjacent stringers and bulkheads. Where a section of skin is damaged to such an extent that it is impossible to install a standard skin repair, a special type of repair is necessary. The particular type of repair required depends on whether the damage is reparable outside the member, inside the member, or to the edges of the panel.

Damage which, after being trimmed, has less than eight and one-half manufacturer's rivet diameters of material inside the members requires a patch which extends over the members, plus an extra row of rivets along the outside of the members. For damage which, after being trimmed, has eight and one-half rivet diameters or more of material, extend the patch to include the manufacturer's row of rivets and add an extra row inside the members. Damage which extends to the edge of a panel requires only one row of rivets along the panel edge, unless the manufacturer used more than one row. The repair procedure for the other edges of the damage follows the previously explained methods.

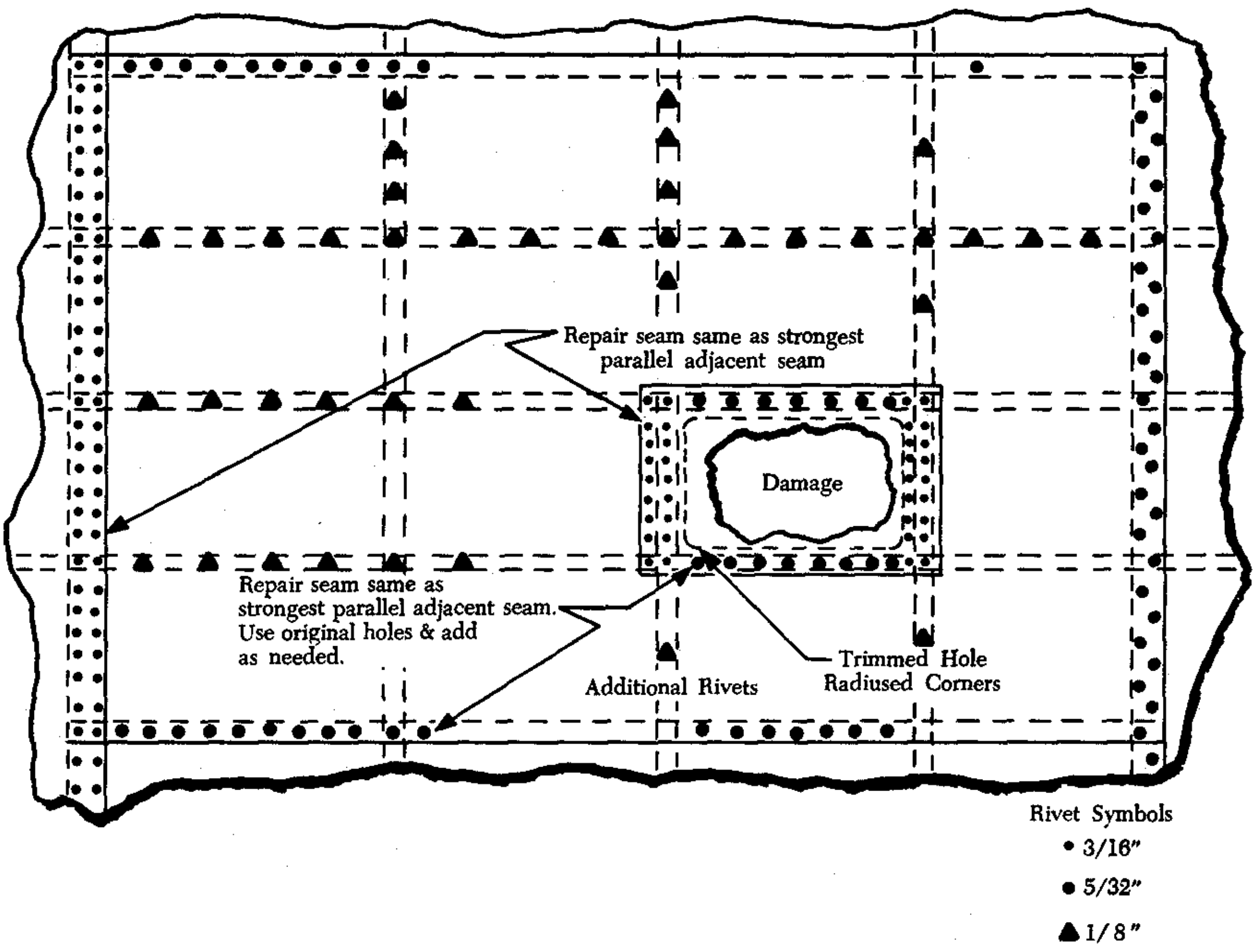


FIGURE 5–78. Panel skin patch.

The procedures for making all three types of panel repairs are similar. Trim out the damaged portion to the allowances mentioned in the preceding paragraph. For relief of stresses at the corners of the trim-out, round them to a minimum radius of ½ in. Lay out the new rivet row with a transverse pitch of approximately five rivet diameters and stagger the rivets with those put in by the manufacturer. See figure 5–78.

Cut the patch plate from material of the same thickness as the original or the next greater thickness, allowing an edge distance of two and one-half rivet diameters. At the corners, strike arcs having the radius equal to the edge distance. Chamfer the edges of the patch plate for a 45° angle and form the plate to fit the contour of the original structure. Turn the edges downward slightly so that the edges fit closely.

Place the patch plate in its correct position, drill one rivet hole, and temporarily fasten the plate in place with a fastener. Using a hole finder, locate the position of a second hole, drill it, and insert a second fastener. Then, from the back side and through the original holes, locate and drill the remaining holes. Remove the burrs from the rivet holes and apply corrosion protective material to the contacting surfaces before riveting the patch into place.

Stringer Repair

The fuselage stringers extend from the nose of the aircraft to the tail, and the wing stringers extend from the fuselage to the wing tip. Surface control stringers usually extend the length of the control surface. The skin of the fuselage, wing, or control surface is riveted to stringers.

Stringers may be damaged by vibration, corrosion, or collision. Damages are classified as negligible, damage reparable by patching, and damage necessitating replacement of parts. Usually the damage involves the skin and sometimes the bulkhead or formers. Such damage requires a combination of repairs involving each damaged member.

Because stringers are made in many different shapes repair procedures differ. The repair may require the use of preformed or extruded repair material, or it may require material formed by the airframe mechanic. Some repairs may need both kinds of repair material.

When repairing a stringer, first determine the extent of the damage and remove the rivets from the surrounding area. Then remove the damaged area by using a hacksaw, keyhole saw, drill, or file.

In most cases, a stringer repair will require the use of an insert and splice angle. When locating the splice angle on the stringer during repair, be sure to consult the applicable structural repair manual for the repair piece's position. Some stringers are repaired by placing the splice angle on the inside, whereas others are repaired by placing it on the outside.

Extrusions and preformed materials are commonly used to repair angles and insertions or fillers. If repair angles and fillers must be formed from flat sheet stock, use the brake. It may be necessary to use bend allowance and sight lines when making the layout and bends for these formed parts. For repairs to curved stringers, make the repair parts so that they will fit the original contour.

When calculating the number of rivets to be used in the repair, first determine the length of the break. In bulb-angle stringers, the length of the break is equal to the cross sectional length plus three times the thickness of the material in the standing leg (to allow for the bulb), plus the actual cross sectional length for the formed stringers and straight angles.

Substitute the value obtained, using the procedure above as the length of the break in the rivet formula, and calculate the number of rivets required. The rivet pitch should be the same as that used by the manufacturer for attaching the skin to the stringer. In case this pitch exceeds the maximum of 10 rivet diameters, locate additional rivets between the original rivets. Never make the spacing less than four rivet diameters.

When laying out this spacing, allow two and one-half rivet diameters for edge distance on each side of the break until all required rivets are located. At least five rivets must be inserted on each end of the splice section. If the stringer damage requires the use of an insertion or filler of a length great enough to justify more than 10 rivets, two splice angles should usually be used.

If the stringer damage occurs close to a bulkhead, cut the damaged stringer so that only the filler extends through the opening in the bulkhead. The bulkhead is weakened if the opening is enlarged to accommodate both the stringer and the splice angle. Two splice angles must be used to make such a repair.

Because the skin is fastened to the stringers, it is often impossible to drill the rivet holes for the repair splices with the common air drill. These holes can be drilled with an angle drill. When riveting a stringer, it may be necessary to use an offset rivet set and various shaped bucking bars.

Former or Bulkhead Repairs

Bulkheads are the oval-shaped members of the fuselage which give form to and maintain the shape of the structure. Bulkheads or formers are often called forming rings, body frames, circumferential rings, belt frames, and other similar names. They are designed to carry concentrated stressed loads.

There are various types of bulkheads. The most common type is a curved channel formed from sheet stock with stiffeners added. Others have a web made from sheet stock with extruded angles riveted in place as stiffeners and flanges. Most of these members are made from aluminum alloy. Corrosion-resistant steel formers are used in areas which are exposed to high temperatures.

Bulkhead damages are classified in the same manner as other damages. Specifications for each type of damage are established by the manufacturer and specific information is given in the maintenance manual or structural repair manual for the aircraft. Bulkheads are identified with station numbers, which are very helpful in locating repair information.

Repairs to these members are generally placed in one of two categories: (1) One-third or less of the cross sectional area damaged, or (2) more than one-third of the cross sectional area damaged. If one-third or less of the cross sectional area has been damaged, a patch plate, reinforcing angle, or both, may be used. First, clean out the damage and then use the rivet formula to determine the number of rivets required in order to establish the size of the patch plate. For the length of the break, use the depth of the cutout area plus the length of the flange.

If more than one-third of the cross sectional area is damaged, remove the entire section and make a splice repair (figure 5–79). When removing the damaged section, be careful not to damage the surrounding equipment, such as electrical lines, plumbing, instruments, and so forth. Use a hand file, rotary file, snips, or a drill to remove larger damages. To remove a complete section, use a hacksaw, keyhole saw, drill, or snips.

Measure the length of break as shown in figure 5–79 and determine the number of rivets required by substituting this value in the rivet formula. Use the double shear value of the rivet in the calculations. The result represents the number of rivets to be used in each end of the splice plate.

Most repairs to bulkheads are made from flat sheet stock if spare parts are not available. When fabricating the repair from flat sheet, remember that the substitute material must provide cross sectional tensile, compressive, shear, and bearing strength equal to the original material. Never substitute material which is thinner or has a cross sectional area less than the original material. Curved repair parts made from flat sheet must be in the "O" condition before forming, and then must be heat treated before installation.

Longeron Repair

Generally, longerons are comparatively heavy members which serve approximately the same function as stringers. Consequently, longeron repair is similar to stringer repair. Because the longeron is a heavy member and more strength is needed than with a stringer, heavy rivets will be used in the

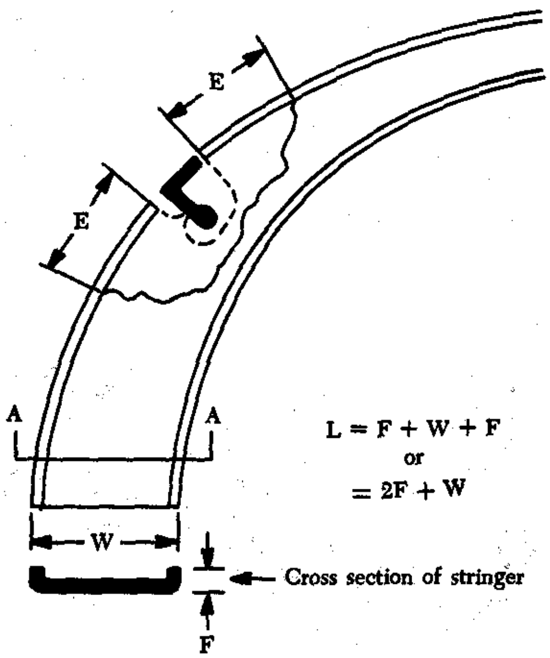


FIGURE 5–79. Determining length of break.

repair. Sometimes bolts are used to install a longeron repair; but, because of the greater accuracy required, they are not as suitable as rivets. Also, bolts require more time for installation.

If the longeron consists of a formed section and an extruded angle section, consider each section separately. Make the longeron repair as you would a stringer repair. However, keep the rivet pitch between four- and six-rivet diameters. If bolts are used, drill the bolt holes for a light drive fit.

Spar Repair

The spar is the main supporting member of the wing. Other components may also have supporting members called spars which serve the same function as the spar does in the wing. Think of spars as the "hub" or "base" of the section in which they are located, even though they are not in the center. The spar is usually the first member located during the construction of the section, and the other components are fastened directly or indirectly to it.

Because of the load the spar carries, it is very important that particular care be taken when repairing this member to ensure that the original strength of the structure is not impaired. The spar is so constructed that two general classes of repairs, web repairs and cap strip repairs, are usually necessary.

For a spar web butt splice, first clean out the damage; then measure the full width of the web section. Determine the number of rivets to be placed in each side of the splice plate by substituting this value for the length of break in the rivet formula. Prepare an insert section of the same type material and thickness as that used in the original web. Make a paper pattern of the rivet layout for the splice plate using the same pitch as that used in the attachment of the web to the cap strip. Cut the splice plates from sheet stock having the same weight as that in the web, or one thickness heavier, and transfer the rivet layout from the paper pattern to the splice plates.

Give all contacting surfaces a corrosion-resistant treatment and rivet the component parts of the repair into place. The rivets used in attaching the insert section to the cap strips are in addition to those calculated for attaching the splice plates. Replace all web stiffeners removed during the repair. An exploded view of a spar web butt splice is shown in figure 5–80.

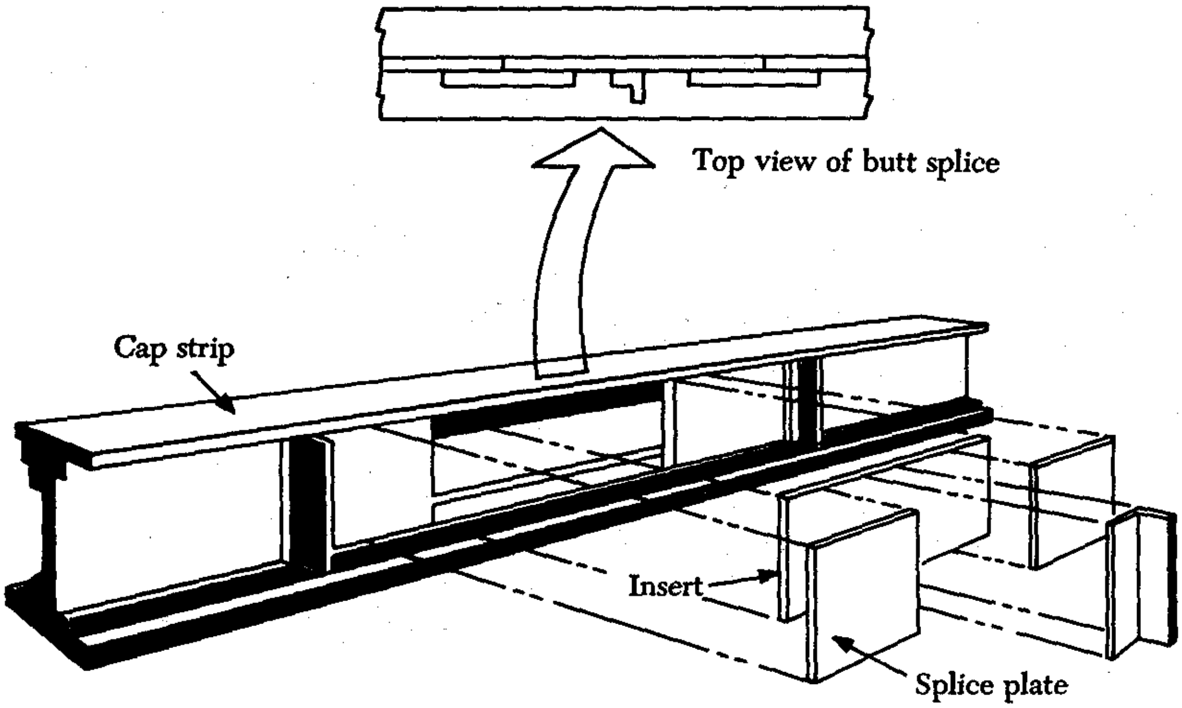


FIGURE 5–80. Spar web butt splice.

When making a spar web joggle splice, no splice plates are needed. Instead, form the web repair section so that it overlaps the original web sufficiently to accommodate the required number of rivets. Make a joggle in each end of the repair section so that the repair piece contacts the cap strips to which it is riveted. Rivet calculation for this repair is similar to that described for butt splicing.

Many forms of cap strips are used in aircraft manufacturing, and each equires a distinct type of repair. In calculating the number of rivets required in an extruded T-spar cap strip repair, take the width of the base of the T, plus the length of the leg as the length of the break, and use double shear values.

Place one-fourth of the required number of rivets in each row of original rivets in the base of the T-section. Locate them midway between each pair of the original rivets. Locate the remainder of the rivets along the leg of the T-section in two rows. Consider all original rivets within the area of the splice as part of the required rivets.

Make the filler piece of a similar piece of T-section extrusion or of two pieces of flat stock. It is possible to make the splice pieces of extruded angle material or to form them from sheet stock; in either case, they must be the same thickness as the cap strip. Figure 5–81 shows an exploded view of a T-spar cap strip repair. The rivets used in the leg of the cap strip may be either the round-, flat-, or brazier-head type; but the rivets used in the base must be the same type as those used in the skin.

The repair of milled cap strips is limited to damages occurring to flanges. Damages beyond flange areas require replacement of the entire cap strip. To make a typical flange repair, substitute the depth of the trimmed-out area as the length of break in the rivet formula and calculate the number of rivets required. Form a splice plate of the required length and drill it to match the original rivet layout. Cut an insert to fit the trimmed-out area and rivet the repair in place. If the trimmed-out area is more than 4 in. in length, use an angle splice plate to provide added strength.

Rib and Web Repair

Web repairs can be generally classified into two types: (1) Those made to web sections considered critical, such as those in the wing ribs, and (2) those considered less critical, such as those in elevators, rudders, flaps, and the like. Web sections must be repaired in such a way that the original strength of the member is restored.

In the construction of a member using a web (figure 5–82), the web member is usually a light-gage aluminum alloy sheet forming the principal depth of the member. The web is bounded by heavy aluminum alloy extrusions known as cap strips. These extrusions carry the loads caused by bending

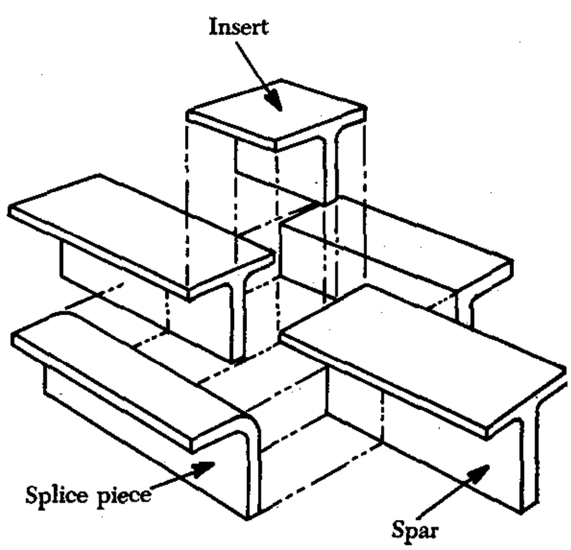


FIGURE 5–81. T-spar cap strip repair.

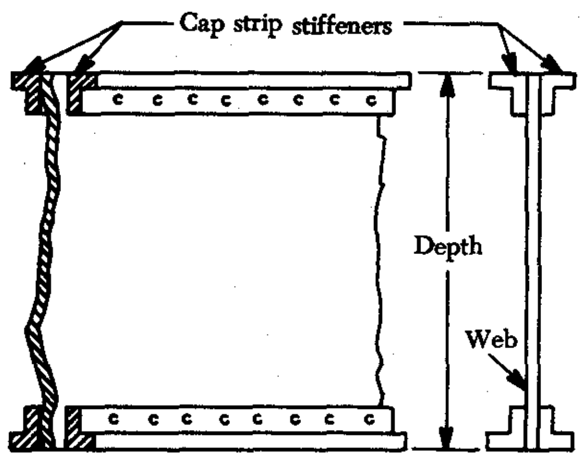


FIGURE 5–82. Construction of a web member.

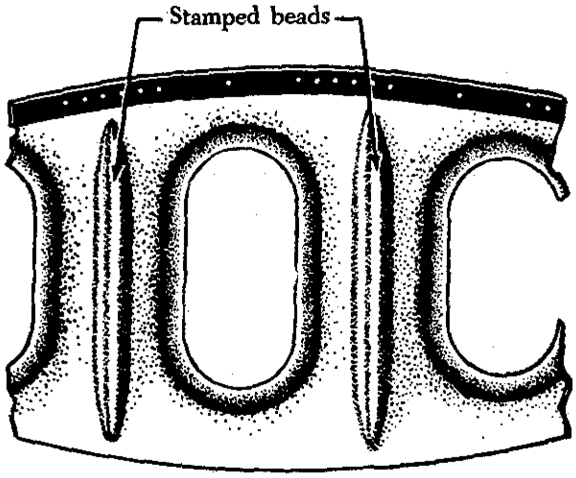


FIGURE 5-83. Stamped beads in a web.

and also provide a foundation for attaching the skin. The web may be stiffened by stamped beads, formed angles, or extruded sections riveted at regular intervals along the web.

The stamped beads (figure 5-83) are a part of the web itself and are stamped in when the web is made. Stiffeners help to withstand the compressive loads exerted upon the critically stressed web members.

Often ribs are formed by stamping the entire piece from sheet stock. That is, the rib lacks a cap strip, but does have a flange around the entire piece, plus lightening holes in the web of the rib. Ribs may be formed with stamped beads for stiffeners, or they may have extruded angles riveted on the web for stiffeners.

Most damages involve two or more members; however, it may be that only one member is damaged and needs repairing. Generally, if the web is damaged, all that is required is cleaning out the damaged area and installing a patch plate.

The patch plate should be of sufficient size to ensure room for at least two rows of rivets around the perimeter of the damage; this will include proper edge distance, pitch, and transverse pitch for the rivets. The patch plate should be of material having the same thickness and composition as the original member. If any forming is necessary when making the patch plate, such as fitting the contour of a lightening hole, use material in the "O" condition and then heat treat it after forming.

Damage to ribs and webs which require a repair larger than a simple plate will probably need a patch plate, splice plates, or angles and an insertion. To repair such a damage by forming the necessary parts may take a great deal of time; therefore, if damaged parts which have the necessary areas intact are available from salvage, use them.

For example, if an identical rib can be located in salvage and it has a cracked web but the area in question is intact, clean out the damaged area; then cut the repair piece from the rib obtained from salvage. Be sure to allow plenty of material for correct rivet installation. Using a part from salvage will eliminate a great deal of hard work plus the heat-treating operation needed by a new repair piece.

Leading Edge Repair

The leading edge is the front section of a wing, stabilizer, or other airfoil. The purpose of the leading edge is to streamline the forward section of the wings or control surfaces so that the airflow is effective. The space within the leading edge is sometimes used to store fuel. This space may also house extra equipment such as landing lights, plumbing lines, or thermal anti-icing systems.

The construction of the leading edge section varies with the type of aircraft. Generally, it will consist of cap strips, nose ribs, stringers, and skin. The cap strips are the main lengthwise extrusions, and they stiffen the leading edges and furnish a base for the nose ribs and skin. They also fasten the leading edge to the front spar.

The nose ribs are stamped from aluminum alloy sheet. These ribs are U-shaped and may have their web sections stiffened. Regardless of their design, their purpose is to give contour to the leading edge.

Stiffeners are used to stiffen the leading edge and supply a base for fastening the nose skin. When fastening the nose skin, use only flush rivets.

Leading edges constructed with thermal anti-icing systems consist of two layers of skin separated by a thin air space. The inner skin, sometimes corrugated for strength, is perforated to conduct the hot air to the nose skin for anti-icing purposes.

Damage to leading edges are also classified in the same manner as other damages. Damage can be caused by contact with other objects, namely, pebbles, birds in flight, and hail. However, the major cause of damage is carelessness while the aircraft is on the ground.

A damaged leading edge will usually involve several structural parts. Flying-object damage will probably involve the nose skin, nose ribs, stringers, and possibly the cap strip. Damage involving all of these members will necessitate installing an access door to make the repair possible. First, the damaged area will have to be removed and repair procedures established. The repair will need insertions and splice pieces. If the damage is serious enough, it may require repair of the cap strip and stringer, a new nose rib, and a skin panel. When repairing a leading edge, follow the procedures prescribed in the appropriate repair manual for this type of repair.

Trailing Edge Repair

A trailing edge is the rearmost part of an airfoil, found on the wings, ailerons, rudders, elevators, and stabilizers. It is usually a metal strip which forms the shape of the edge by tying the ends of a rib section together and joining the upper and lower skins. Trailing edges are not structural members, but they are considered to be highly stressed in all cases.

Damage to a trailing edge may be limited to one point or extended over the entire length between two or more rib sections. Besides damage resulting from collision and careless handling, corrosion damage is often present. Trailing edges are particularly subject to corrosion because moisture collects or is trapped in them.

Thoroughly inspect the damaged area before starting repairs, and determine the extent of damage, the type of repair required, and the manner in which the repair should be performed. When making trailing edge repairs, remember that the repaired area must have the same contour and be made of material with the same composition and temper as the original section. The repair must also be made to retain the design characteristics of the airfoil.

Damage occurring in the trailing edge section between the ribs can be repaired as shown in figure 5–84. Cut out the damaged area and make a filler of either hardwood, fiber, or cast aluminum alloy to fit snugly inside the trailing edge. Then make an insert piece of the same material as the damaged section and shape it to match the trailing edge. Assemble the pieces as shown and rivet them into place using countersunk rivets and forming countersunk shop heads to get a smooth contour.

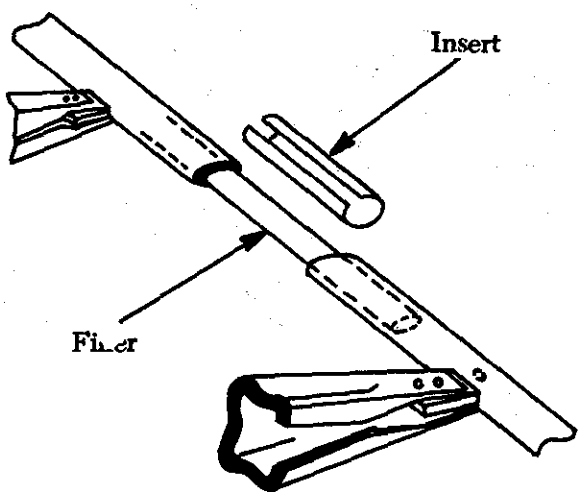


FIGURE 5–84. Trailing edge repair between ribs.

To repair damage occurring at or near a rib, first remove sufficient trailing edge material to allow a complete splice to fall between the ribs. This usually requires two splices joined by an insert piece of similar trailing edge material or of formed sheet stock. The repair procedure is similar to that for damage between ribs. Figure 5–85 shows this type of repair.

STRUCTURAL SEALING

Various areas of airframe structures are sealed compartments where fuels or air must be confined. Some of these areas contain fuel tanks; others consist of pressurized compartments such as the cabin. Because it is impossible to seal these areas completely airtight with a riveted joint alone, a sealing compound or sealant must be used. Sealants are also used to add aerodynamic smoothness to exposed surfaces such as seams and joints in the wings and fuselage.

Three types of seals are ordinarily used. Rubber seals are installed at all points where frequent breaking of the seal is necessary, such as emergency exits and entrance doors. Sealing compounds are used at points where the seal is seldom broken

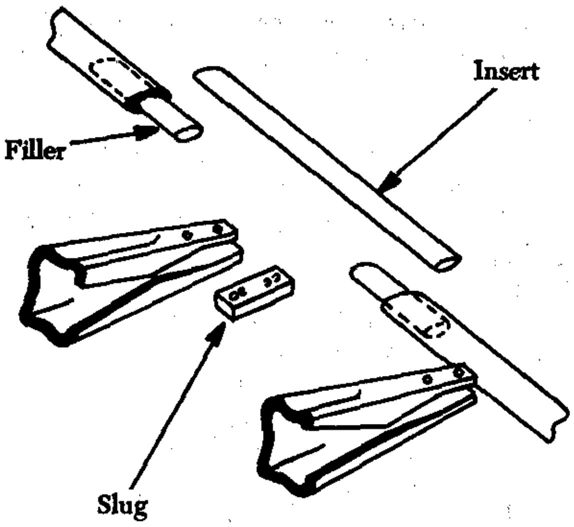


FIGURE 5-85. Trailing edge repair near a rib.

except for structural maintenance or part replacement, as with riveted lap and butt seams. Special seals are required for passing cables, tubing, mechanical linkages, or wires out of the pressurized or sealed areas.

Wires and tubes are passed through pressure bulkheads by using bulkhead fittings such as cannon plugs for wiring and couplings for tubing. These fittings are sealed to the bulkhead and the wires and tubes are fastened to them from each side. All seals of moving components such as flight controls are subject to wear and utmost care must be used when they are installed. Also, they must be checked regularly.

Determining Sealant Defects

Pressure tightness of an area or section is checked before and after a repair is made. Ground pressurization is accomplished by filling the section with air from an external source through ground pressure test fittings.

With the sections pressurized to a given pressure, locate leaks on the outside of the aircraft by applying a soapless bubble solution to all seams and joints in the suspected area. Air bubbles will locate the general area of leakage. A specific leak is then isolated on the inside of the aircraft by passing the free end of a stethoscope or similar listening device along the seams in the leakage area. The leak can be detected by the change in sound when the instrument passes over it. After completing the test, remove the soapless bubble solution from the outside of the aircraft by washing with clear water to prevent corrosion.

Here are a few precautionary measures to follow during the testing procedure just discussed. With personnel inside, the area should never be pressurized to a pressure higher than has previously been established during testing with the section empty. No person who has a cold or who has recently had one, or whose sinuses are impaired in any way, should work in the pressurized section. A qualified operator should be present at the pressurization equipment control panel at all times while the section is being pressurized.

Pressurization may not always be necessary to determine defectively sealed areas. Sealants should be repaired when:

(1) Sealants have peeled away from the structure.

(2) Seams are exposed through the sealant fillet.

(3) Fillet- or hole-filling sealant is exposed through the smooth overcoating.

(4) Sealant is damaged by the removal and re-installation of fasteners, access doors, or other sealed parts.

(5) Cracks or abrasions exist in the sealant.

Sealant Repair

All surfaces which are to be sealed must be cleaned to ensure maximum adhesion between the sealant and the surface. Loose foreign material can be removed by using a vacuum cleaner on the affected area. Scrape all the old sealant from the repair area with a sharp plastic, phenolic, or hardwood block to prevent scratches, and apply a stripper and a cleaner.

The cleaner should not be allowed to dry on a metal surface, but should be wiped dry with clean rags. Do not remove the cleaner with soiled rags since the metal surface must be free of all dirt, grease, powder, and so forth. The surface can be checked for cleanliness by pouring water over it after being wiped dry of the cleanser. If the surface is not free of oily film, the water will separate into small droplets.

Be extremely careful to protect any undamaged sealant and acrylic plastics from the stripper compound. If artificial lighting is used when the repair is made, be sure the light is of the explosion proof type. Wear clothing which affords adequate protection from the stripper and cleaner so that these chemicals cannot contact the skin. Provide adequate ventilation in the work area. Personnel should wear a respirator when working in an enclosed area.

It may be necessary to replace rubber seals periodically to ensure tight door closure. Seals of this type should be replaced any time there is any degree of damage. Such a seal is usually not reparable because it must be continuous around the opening.

To remove the old seal, remove all the seal retainers from the frame and then pull off the old seal. Use aliphatic naphtha and clean rags to clean the frame on which the new seal is to be cemented. Cleaning should be done immediately before sealer installation. Then, using a clean paint brush, apply an even coat of rubber cement upon the metal parts and the seal surfaces which are to be joined.

Allow the rubber cement to dry until it becomes quite sticky. Then join the seal to the metal by pressing it firmly along all contact points. Install the seal retainers and allow the seal to set for at least 24 hrs. before using.

Toluene may be used for cleaning brushes and other equipment used in applying rubber cement. If the rubber cement needs thinning, use aliphatic naphtha.

Seals on pressurized sections must be able to withstand a certain amount of pressure. Therefore, damage to the seals in the compartment or section must be repaired with this question in mind: Can it withstand the pressures required? Pressure sealing must be performed on the pressurized side of the surface being sealed. Make sure that all areas are sealed before completing further assembly operations which would make the area inaccessible.

Sealing compounds should be applied only when the contacting surfaces are perfectly clean. The compound should be spread from the tube by a continuous forward movement to the pressure side of the joint. It is advisable to start the spreading of the compound 3 in. ahead of the repair area and continue 3 in. past it. If the compound is in bulk form, apply it with a pressure gun. Two coats or layers of compound are often required. If this is necessary, let the first application cure before the second is applied. Allow the compound to cure until it becomes tough and rubbery before joining the surfaces.

Curing time varies with temperature. High temperatures shorten the curing time and low temperatures lengthen it. Artificial heat may be used to speed up curing, but care must be used to avoid damaging the sealant with too high a temperature. Warm circulating air, not over 120°F., or infrared lamps placed 18 in. or more from the sealants are satisfactory heat sources. If infrared lamps are used, adequate ventilation must be provided to carry away the evaporated solvents.

Sealing compounds are most generally used on seams and joints, but they may also be used to fill holes and gaps up to $\frac{1}{16}$ in. wide.

Impregnated zinc chromate tape is sometimes used between seams and joints. Sealing tape is also used as a backing strip over holes and gaps which are $\frac{1}{16}$ to $\frac{1}{2}$ in. in width. The tape is applied over the opening on the pressure side, and a fillet of sealing compound is applied over the tape. Holes and gaps over $\frac{3}{16}$ in. in width are usually plugged with wood, metal caps, or metal plugs on the pressure side of the area; then, impregnated tape and sealing compound are applied over the repair.

Be sure that all forming, fitting, and drilling operations have been completed before applying the tape. With the repair surface area clean, unroll the tape with the white cloth innerleaf away from the metal surface. Leave the innerleaf on the tape until just before the parts are assembled. There must be no wrinkles in the tape, and the parts must be joined together with the least possible amount of sideways motion.

The application of putty sealant is similar to that of sealing compounds. A spatula or sharp-pointed plastic, phenolic, or hardwood block is sometimes used to force and pack the putty into the gaps or seams. Clean the gap or seam with compressed air before applying the putty to the pressure side.

Rivets, bolts, or screws do not always seal properly when used in these critical areas or sections. When pressure leaks occur around the fasteners, they should be removed and replaced. The holes should be filled with sealing compound and new fasteners installed. Remove excess sealant as soon as possible to avoid the difficulty encountered after it becomes cured.

METAL BONDED HONEYCOMB

The introduction of bonded honeycomb (sandwich construction) members in airframe design and manufacture came as a major breakthrough in the search for a more efficient type of structure. Because bonded honeycomb structures are manufactured and perform their jobs in a manner different from the previously used and more familiar conventional structures, new attitudes and methods of repair had to be developed with respect to the advantages, limitations, and physical peculiarities.

CONSTRUCTION FEATURES

Sandwich construction design is governed by the intended use of the panel or structure. It can be defined as a laminar construction consisting of a combination of alternating dissimilar materials, assembled and fixed in relation to each other so that the properties of each can be used to attain specific structural advantages for the whole assembly.

Sandwich-constructed assemblies can be found in a variety of shapes and sizes on modern aircraft. They may consist of a whole section or a series of panels combined into an assembly. Sandwich-constructed assemblies are used for such areas as bulkheads, control surfaces, fuselage panels, wing panels, empennage skins, radomes, or shear webs.

Figure 5–86 illustrates a section of bonded honeycomb. The honeycomb stands on end and separates facings which are bonded to the core by means of an adhesive or resin. This type of construction has a superior strength/weight ratio over that of conventional structures. Also, it is better able to withstand sonic vibration, has relatively low cost when compared with fastener cost and installation of conventional structures, reduces the number of parts needed, and greatly reduces sealing problems while increasing aerodynamic smoothness.

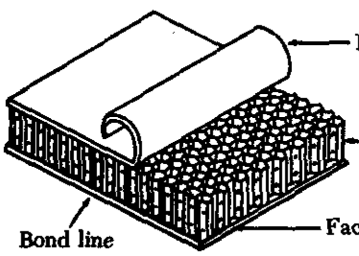


FIGURE 5–86. Bonded honeycomb section.

Special applications of metal-bonded honeycomb may employ stainless steel, titanium, magnesium, plywood, resin-impregnated paper, glass, nylon, or cotton cloth in various combinations.

DAMAGE

Causes of Damage

The majority of damages to bonded honeycomb assemblies result from flight loads or improper ground handling. Honeycomb structures may also be damaged by sonic vibrations. Such damage is usually a delamination or separation of the core and face along the bond line. (The bond line is the thin line of adhesive between the core and the face that holds the two together.) Occasionally the core may collapse.

Damage Inspection

Inspection for damage is more critical for honeycomb assemblies than for conventional structures. A honeycomb structure can suffer extensive damage without any observable indication. Sonic vibration, liquid leakage, internal condensation, or a misstep in manufacture or repair can cause or result in varied amounts of delamination.

The metallic ring test is the simplest way to inspect for delamination damage. When a coin (25-cent piece) is lightly bounced against a solid structure, a clear metallic ring should be heard. If delamination is present, a dull thud will be heard. A 1-oz. aluminum hammer makes an excellent tool for this type of inspection.

Occasionally, the delaminated skin will "oilcan" away from the core, making visual or thumb pressure detection possible. Punctures, dents, scratches, cracks, or other such damage may be inspected by conventional methods. Scratches should be given special attention since, with such thin material as that used in the metal bonded honeycomb, the scratch may actually be a crack.

A caustic soda solution can be used for testing scratches on aluminum surface panels. If the scratch area turns black after the application of a small amount of the solution, the scratch has penetrated through the clad surface. Caustic soda solutions are highly corrosive and must be handled with extreme care. Thoroughly neutralize the area after application of the solution.

Two additional instruments used in damage inspection of bonded panels are the panel inspection analyzer and the borescope.

Damage Evaluation

After inspections on metal bonded honeycomb structures are completed, any damage found must be evaluated to determine the type of repair needed to make the structure serviceable.

Damage to aluminum honeycomb structures can vary from minor dents or scratches to total panel destruction. Damage evaluation charts for honeycomb structures can be found in the applicable section of the structural repair manual for the specific aircraft. The charts specify types of damage, allowable damage, damage requiring repair, and figure numbers that illustrate similar repairs for each type of damage.

Once the type of repair is determined, procedures outlined in the structural repair manual should be rigidly followed.

REPAIRS

Recommendations for the type of repair to make and the methods or procedures to use vary among the different aircraft manufacturers. Tools, materials, equipment, and typical repairs that might be made on metal bonded honeycomb structures will be discussed in the following paragraphs.

Tools and Equipment

Effective repairs to bonded honeycomb assemblies depend largely on the knowledge and skill of the airframe mechanic in the proper use and maintenance of the tools and equipment used in making bonded honeycomb repairs. The design and high quality of workmanship built into these tools and equipment make them unique in the repair of bonded honeycomb assemblies. Therefore, it is essential that the techniques and procedures established for each tool or piece of equipment be known and practiced. Both personal injury and additional damage to the area being repaired can then be avoided.

Router

The primary tool used to prepare a damaged honeycomb area for repair is a pneumatically powered, hand-operated router with speeds ranging from 10,000 to 20,000 r.p.m. The router is used in conjunction with the support assembly, bit, and template as shown in figure 5–87.

The router support assembly threads onto the router body. It has provisions to adjust the desired depth of the cut with a locking (clamping nut) mechanism which secures the depth adjustment in place. One complete turn of the support adjustment changes the depth of cut approximately 0.083 in.

Metal-cutting, ¼-in. mill bits are used with the router for removing the damaged areas. The router bits should be kept sharp, clean, and protected against nicks, breakouts, or other damages.

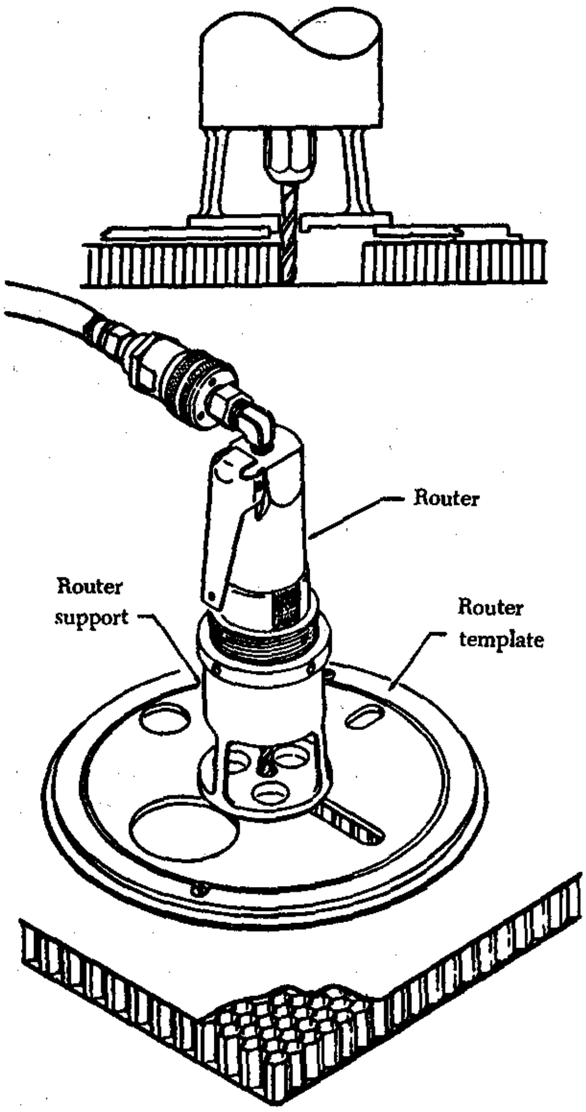


FIGURE 5–87. Router, support assembly, and template.

Router templates are used as guides when removing damaged honeycomb areas with a router. They can be designed and manufactured to the desired sizes, shapes, or contours of the repair. As an example, the multi-template (figure 5–88) can be used as a guide when cutting holes from ½ in. to 6 in. in diameter. For larger holes, a template can be manufactured locally from aluminum alloy 0.125-in. thick, whereas smaller holes can be cleaned out without the use of a template. The multi-templates should be kept clean and lightly oiled to prevent rusting and to maintain smooth operation during their use.

A routing template may be applied to a flat surface using the following procedures:

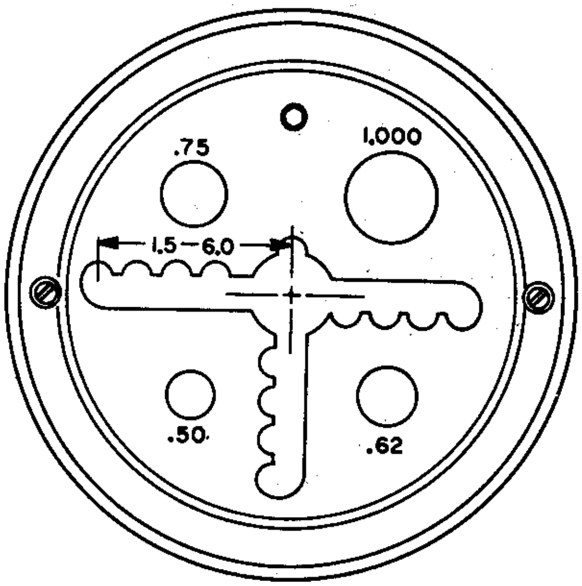


FIGURE 5–88. Multi-template.

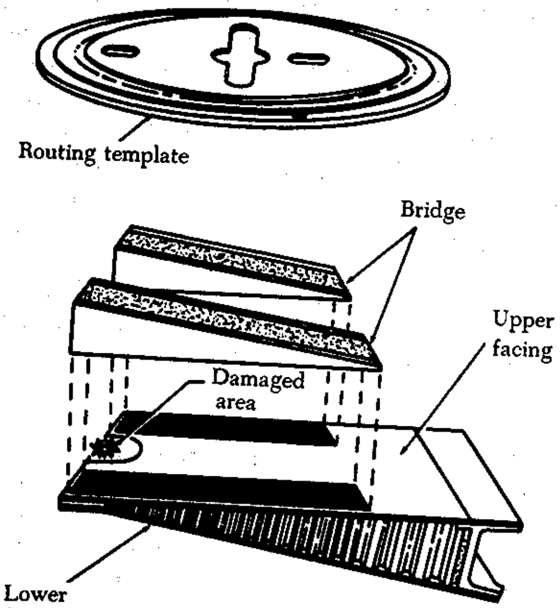


FIGURE 5–89. Wedge blocks and application.

(1) Apply double-backed tape to the edge or rim of the routing template.

(2) Place the template, centering the desired cutout guide hole directly over the damaged area.

(3) Press the template firmly down over the double-backed tape, making sure that it is secured in place; this will avoid any creeping or misalignment of the template during the routing operation.

A routing template may be applied to a tapered surface by using the follwoing procedures:

(1) Manufacture a bridge consisting of two wooden wedge blocks at least 6 in. long and with approximately the same degree of angle as that of the panel. (See figure 5–89.)

(2) Apply a strip of double-backed tape to one side of each wedge block.

(3) Place a wedge block on each side of the damaged area in a position that will bridge and support the template properly during the routing operation.

(4) Press the wedge blocks firmly in place.

(5) Place another strip of double-backed tape on the top side of each wooden wedge block.

(6) Place and align the template over the wedge blocks, thus avoiding any creeping or misalignment of the template during operation.

Routing of Damaged Areas

When the extent of damage and type of repair have been determined, the proper size hole of the router template must be located around the damaged area in such a way that it will ensure that all the damage will be removed. The double-backed tape is used to secure the template to the surfaces around the damaged area, thus preventing creeping or misalignment of the template.

The router bit should be adjusted and set for the approximate depth required to remove the damaged area. During the routing operations, the router should be firmly gripped with both hands to prevent it from jumping or creeping. When the router is not in use, it should be disconnected from the air hose and stored properly until it is to be used again.

The following procedures for the removal of damaged bonded honeycomb areas are typical of those used by the various airframe manufacturers. Always follow the repair techniques specified by the applicable aircraft manufacturer.

(1) Determine the extent of the damage.

(2) Set up and adjust the router, router support assembly, and end-cutting mill bit for the removal of the damaged area.

(3) Select a routing template and position the template over the repair area according to procedures outlined in the discussion on templates.

(4) Attach the router's air intake plug in the socket of the air supply.

(5) Accomplish the routing operation.

(a) Use face shield or goggles for eye protection against flying materials removed.

(b) Place the air hose over the shoulder.

(c) Holding the router firmly and at a 45° angle to the surface, place one edge of the router support assembly against the edge of the routing template.

(d) Start the router by depressing the control lever.

(e) Carefully, but firmly, lower the end-cutting mill bit into the material as close as possible to the center of the damaged area to be removed.

(f) Straighten the router to be perpendicular to the surface.

(g) Holding the router firmly, spiral it clockwise to the outer limits of the template's guide hole, removing all the damaged material.

(h) Release the control lever, allow the router to stop, and remove it from the hole.

(i) Disconnect the router from the air supply.

(j) Check the damaged area removed. If additional removal is required, adjust the router's cutting depth and repeat routing operation.

(6) Upon completion of the routing operation, disconnect and clean the routing equipment.

During the routing operations, the aluminum core cells of a damaged honeycomb area tend to bend or close up. Therefore, they must be opened with tweezers and a pen knife before any further attempts to repair are made. At times, the core cells must be trimmed with a pen knife to the shape of the repair hole.

Pressure Jigs

Pressure jigs are used to apply pressure to repairs on the under surfaces of honeycomb panels or assemblies to hold the repair materials and resins in place. The pressure is maintained on the repair area until the repair material is cured.

C-clamps, locally manufactured jigs, or vacuum fixtures may be used to apply the necessary pressure to bonded honeycomb repairs.

The surfaces around the repair area must be absolutely clean and free of any foreign materials to ensure a good vacuum when vacuum fixtures or suction types of equipment are used. An application of water or glycerin to the surface areas will aid in obtaining a good vacuum. Normal cleaning, care, and corrosion prevention will maintain the above equipment in good working condition.

Infrared Heat Lamps

Infrared heat lamps are used to shorten the curing time of bonded honeycomb repairs from approximately 12 hrs. to 1 hr. A single-bulb lamp will adequately cure a repair up to 6 in. in diameter, but a large repair may require a battery of lamps to ensure uniform curing of the repair area.

The lamps should be centered directly over the repair at a distance of about 30 in. The setup is ideal to attain the recommended 130° F. curing temperature, provided the surrounding areas are at room temperature (70° F.). Warmer or colder surrounding areas will require that the heat lamps be adjusted to the prevailing condition. Caution must be used when working under extremely cold conditions, since a temperature differential of 150° or more will cause buckling of the surrounding skin surfaces because of thermal expansion.

As with any ordinary light bulbs, the infrared bulbs require little or no maintenance; however, the support stands, wiring, and switches should be handled carefully and maintained properly.

Fire Precautions

The potential of a fire hazard generally exists in the area of bonded honeycomb repairs because of the low flash point of the repair materials, such as cleaning solvents, primers, and resins. Therefore, it is necessary that all fire precautions be observed closely. Certain fire safety prevention equipment, such as utility cans, flammable-waste cans, and vapor- and explosion-proof lights, should be used.

With the potential of fire hazards in a honeycomb repair area, it is necessary to make sure that a suitable fire extinguisher is on hand or is located nearby and ready for use, if necessary. The extinguishing agents for all the materials used in bonded honeycomb repairs are dry chemicals or carbon dioxide; thus, the standard CO_2 fire extinguishers should be on hand for use in areas where bonded honeycomb structures will be repaired.

Handtools and Equipment

In addition to the tools and equipment described in the preceding paragraphs, standard handtools and shop equipment are utilized in the repair of bonded honeycomb structures. Standard handtools and shop equipment used in the shop include an airframe mechanic's tool kit, face shields, scissors, power shear, drill press, horizontal and vertical belt sanders, contour metal-cutting saw, and pneumatic hand drills. The general uses and maintenance of these standard tools and equipment should be familiar to any airframe mechanic.

REPAIR MATERIALS

Cleaning Solvents

Before any repair is made to a bonded honeycomb structure, an area extending several inches away from the damage must be cleaned thoroughly of all paint or surface coating. This is best accomplished by the use of paint remover or MEK (methyl-ethyl-ketone) cleaning solvent. In some cases, Alconox, a powerful wetting and detergent agent, may be used for a final cleanup to remove any residue or oils remaining after application of the paint remover or the MEK cleaning solvent.

Paint removers are applied with a suitable size brush. When the paint or surface coating has loosened, it is either wiped off with a clean rag or removed with a nonabrasive scraper. Paint remover must not be allowed to enter the damaged area or be used along a bonded joint or seam because its chemical action will dissolve the bonding adhesive. These areas should be masked and final cleanup accomplished with the MEK cleaning solvent or emery cloth. The MEK cleaning solvent and the Alconox cleaning agent may be applied with a clean sponge.

After a damaged area has been completely removed, the surrounding surface areas must be thoroughly re-cleaned. This is accomplished by the use of the MEK cleaning solvent and gauze sponges. The MEK cleaning solvent is applied to the area with one sponge and immediately wiped off with another before it has had time to dry. This cleaning process should be continued until the surface area is lusterous in appearance and clean of any foreign matter.

To determine whether an area is completely and thoroughly clean, a water "break" test can be used. This test is a simple application of a thin film of distilled water to the cleaned area. Any "break" of the applied thin film of distilled water will indicate that the area has not been cleaned thoroughly enough and the cleaning process must be repeated.

Safety precautions must be closely observed when working with the above solvents, especially when the work is overhead or when working in confined areas. For personal protection, rubber gloves, face shields, adequate ventilation, and respirators should be worn. A CO_2 fire extinguisher should be on hand or nearby and ready for use if necessary.

Primers

Primers are applied to the cleaned surface areas primarily to ensure a good bond of the honeycomb repairs. The primer is applied to the cleaned surface areas with a clean gauze sponge or suitable brush. It is recommended that the primer be applied as rapidly as possible because it will become tacky in 10 to 15 sec., and it will pull and be ruined by any further brushing. The primer will cure in approximately 1 hr. at room temperature; however, this time may be reduced by the application of controlled heat.

Adhesives and Resins

Two types of adhesives presently used in the repairs of bonded honeycomb structures of some aircraft are known as the type 38 adhesive and the potting compound. The type 38 adhesive is applied to glass fabric overlay repairs, and the potting compound, as the name implies, to the potted compound (hole filling) repairs. In addition, the type 38 adhesive may be used as an alternate for the potting compound by adding micro-balloons (microscopic phenolic). The adhesives or potting compounds are prepared according to a batch mix (amount required for the repair) formula. The batch mix should be measured by weight.

Accurate mixing of the adhesive ingredients by batches is considered one of the more important steps in the repair of bonded honeycomb structures. The correct proportions of the epoxies, resins, and micro-balloons to be mixed into batches, both by weight and/or by volume, are given in the applicable section of the structural repair manual for the specific aircraft.

Core Material

Fiberglass honeycomb core materials ($\frac{3}{16}$ in. cell size) are usually used to replace the damaged aluminum cores of the bonded honeycomb structures. Aluminum core materials are not satisfactory for the repairs because of their flimsy and fragile structure. With this condition, it is impractical to cut the aluminum core materials accurately to the desired repair size. Fiberglass core materials are available in various thicknesses and are easily and accurately cut to size by the use of standard shop tools and equipment.

Glass Fabrics

Glass fabrics used in the overlay repairs to bonded honeycomb structures are manufactured from glass. The glass is spun into fibers which are in turn woven into a glass cloth with a variety of weaves.

Glass fabric cloth must be handled with care, stored properly, and be perfectly clean (free of any dirt, moisture, oil or other contaminants which may cause imperfect adhesion of the adhesives with which it is impregnated). Snags and sharp folds in the cloth will cause its strands to break, resulting in a local strength loss in the finished repair. Exposure to or contact with the glass fabric, dust, or particles may cause bodily itching or irritation.

Erosion and Corrosion Preventives

Two coatings of preventives are applied to the bonded honeycomb structure repairs to protect the areas against erosion and corrosion. The first is two layers of zinc chromate, preferably sprayed onto the repair area. The second is two layers of aluminum pigmented Corrogard (EC843), or equal, either sprayed or brushed on with a 30-min. drying period between each application. Both materials are flammable; therefore, the necessary fire precautions should be observed.

POTTED COMPOUND REPAIR

The following techniques, methods, and procedures are related to potted compound repairs and are typical of those used on most bonded honeycomb structures. For all repairs, consult the applicable section of the structural repair manual. The manufacturer's procedures should always be followed.

Bonded honeycomb structure damages up to 1 in. in diameter may be repaired by a hole-filling technique, using approved materials. The repair method is commonly known as the "potted compound repair." It is the easiest and fastest method of repairing a damaged area of a bonded honeycomb structure. However, be sure to follow the techniques, methods, or procedures established for potted compound repairs to avoid any further damage which might result in a more complicated repair.

Potted compound repairs may be applied both to single-face (one skin) and core damages, or to double-face (two skins) and core damages. (See figure 5–90.)

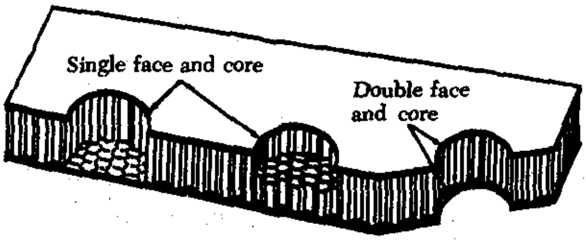


FIGURE 5–90. Typical potted compound repair areas.

Removal of Damage

Normally, no surface preparation is necessary when performing potted compound repairs. Oily or dirty surface areas to which multi-templates or pressure jigs are attached with adhesive tapes should be cleaned with any approved or recommended cleaning solvents, such as MEK.

Damages 1/4 in. or less in diameter can be satisfactorily removed with a twist drill. The multi-template and a high-speed router (10,000 to 20,000 r.p.m.) should be employed in the removal of damaged areas for potted compound repairs up to 1 in. in diameter. The amount of material removed by either method must be kept to a minimum to maintain as much of the original strength of the panel or structure as possible. Always use a face mask or protective glasses when using the router to remove damaged materials.

Repair Techniques

After a damaged area has been completely removed and cleaned, the necessary materials for the potted compound repair(s) are prepared.

Pieces of sheet plastic materials are prepared to provide a smooth surface effect of the potted compound repair, to provide part of the reservoir for the hole (cavity) filling operation of the repair, and to hold the potting compound in place until it is completely cured. The pieces of sheet plastic to be used for any or all of the above purposes should be at least 1/2 in. larger in diameter than the repair hole diameter.

A thinner piece of sheet plastic material (approximately 1/16 in. thick) is applied to the lower (bottom) surface of the double-face repair (figure 5–91). This is done not only to give the repaired surface a smooth effect, but mainly to hold the repair surface (potting compound) in place until it is cured. The same may be applied to a single-face

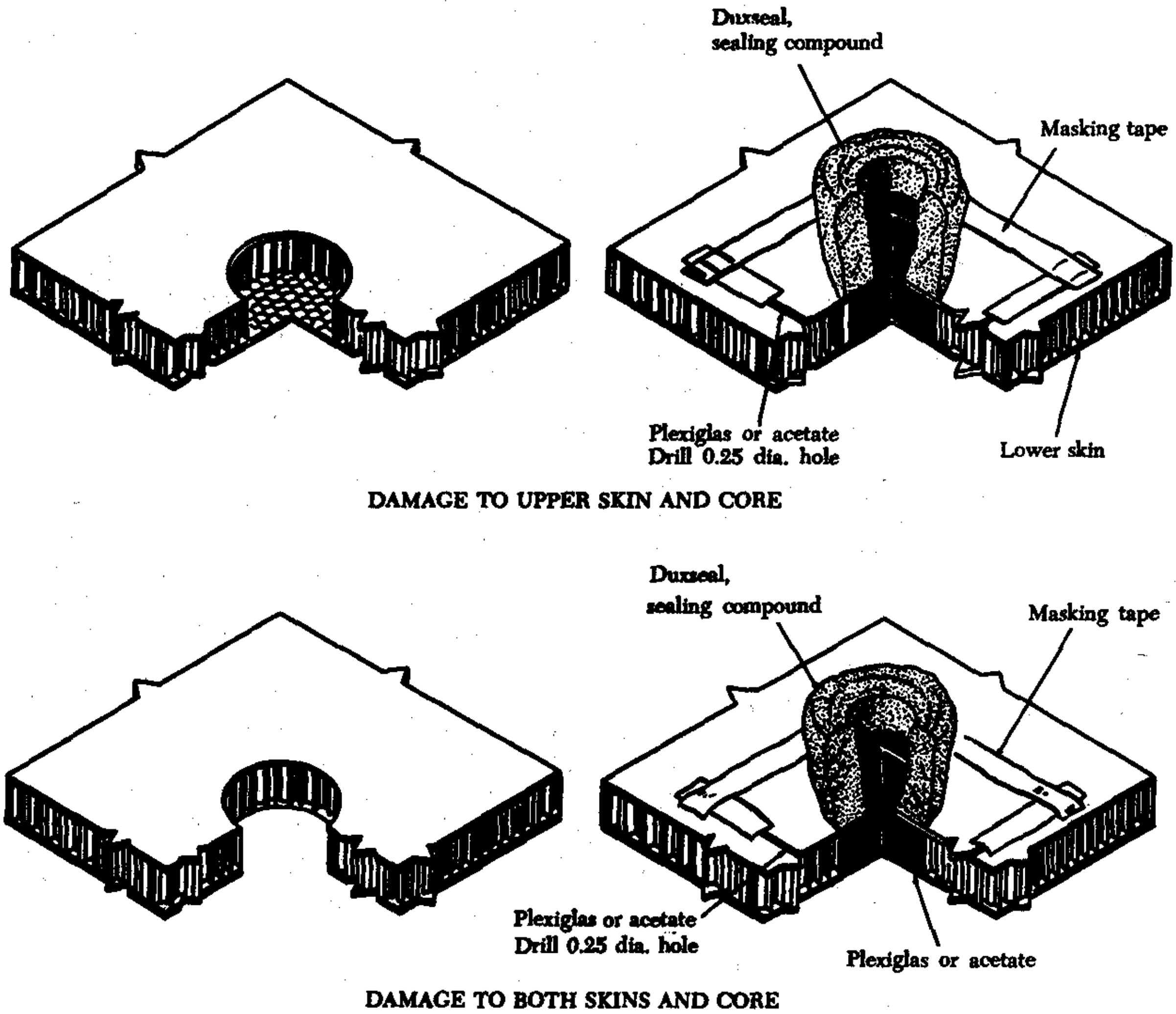


FIGURE 5-91. Potted compound repairs.

repair where the work must be accomplished in an overhead position.

Sheet plastic materials ranging from 1/4 in. to 3/16 in. in thickness are used on the upper (top side) surface of the repair during the hole (cavity) filling procedures. A 1/4-in. hole is drilled directly in the center to permit easy application of the potting compounds to the repair cavity. The hole is also countersunk, allowing a buildup of the potting compound and thus assuring that the repair cavity has been completely filled.

This piece of plastic material is also a part of the "Duxseal" dam. After the prepared pieces of sheet plastic materials are properly located and taped in place over the repair area, the Duxseal (or equal) dam is built up around the hole. (See figure 5-91.) This dam is partially filled with the potting compound during the hole-filling operation to ensure an adequately filled repair cavity. The dam also acts as the reservoir.

Next, a sufficient batch mix of the potting compound is prepared for the repair. The cavity is filled with the potting compound, and the air bubbles are removed with a toothpick or similar tool. The air bubbles are removed to ensure that the repair cavity is solidly filled.

When the potting compound within the repair cavity is completely cured, the pieces of plastic may then be removed. Generally, these pieces of plastic can be lifted off by hand; but, if necessary, they can be pried off easily with any dull straight hand-tool. When the drilled top piece of plastic is removed, it will leave a broken stem protruding above the repair surface. This stem may be filed, microshaved, or routed down to make the repair surface area smooth.

The soundness of the repair can be tested by the metallic ring test. Pressure jigs may be used on the undersurface potted repairs as necessary. The repair is surface finished by the application of the recommended coatings of erosion or corrosion preventives, and a final coating of a finish of the same specifications as that of the original finish.

GLASS FABRIC CLOTH OVERLAY REPAIRS

Presently, two acceptable methods of repair are being applied to the damaged skin and core materials of some aircraft bonded honeycomb structures. One is the potted compound repair method previously discussed, and the other is the laminated glass fabric cloth overlay method applied to the various damages of honeycomb skin and core materials which exceed the repair limitations of the potted compound repair.

The differences between the two repair methods are in the techniques of removing the damaged area, preparing the damaged area for the repair, preparing and applying the repair materials, finishing and final inspection of the completed repair, and use and maintenance of the handtools and shop equipment.

Cleaning

Before repairing a damaged bonded honeycomb panel or section, thoroughly clean all paint or surface coatings from a surface area extending several inches away from the damage. Basically, this is necessary to attach and secure the templates or wedge blocks to the repair area with double-backed tape. Second, thoroughly clean the area of all foreign matter to ensure a perfect adhesion of the overlay repair materials.

Effective surface cleaning is of primary importance to the success of any repair. An area that is contaminated with paint, grease, oil, wax, oxides, or such, will not take a good bond. This cannot be emphasized too strongly since the quality of the repair will be no higher than the quality of the cleaning that precedes it. Even a fingerprint will prevent a good bond, because of natural oils in the skin.

Materials such as solvents, abrasives, alkaline detergents, and chemical etches can be used for effective cleaning. One of the easiest and most effective cleaning methods known is to apply MEK to the area with a sponge and immediately wipe it away with another sponge. This procedure should be continued until a lusterous surface is obtained.

In removing paint, use caution, since paint remover will dissolve adhesives if allowed to enter the damaged area of a joint.

Removal of Damage

A high-speed router in conjunction with a router support assembly, metal-cutting mill bit, and template should be used in the removal of the damaged area. (Information about the uses and maintenance of the router was discussed earlier in this chapter.)

The techniques of removing damaged honeycomb skin and core material may differ from one repair to another. Their selection depends largely on the construction features of the bonded honeycomb panels, which are primarily of either flat, tapered, or combined (flat and tapered) surface design. Also, the location of the damaged area must be considered; that is, whether the damage occurred on the upper or lower side of the panel. Another factor that must be considered is that the honeycomb core is always installed within the panel with the cells perpendicular to the lower surface.

The techniques of preparing for and removing a damaged area on a tapered or upper surface of a panel are somewhat different from those for a flat or lower surface. Prior to the routing of a damaged area of an upper or a tapered surface, the routing template must be bridged over the repair area. This is done in such a manner that the routing template will be perpendicular to the core cells and parallel to the opposite (lower) facing. The bridge consists of two wedge blocks made of wood, at least 6 in. long, approximately 2 in. wide, and tapered to the same degree of angle as that of the panel. The method by which the bridge is attached to the damaged area is shown in figure 5–89.

Adhesives

Overlay repair adhesives consist of a type 38 batch mix. Micro-balloons are added to the resins and curing agent for "buttering" the fiber glass honeycomb core plug and cavity of the glass cloth overlay repair. The micro-balloons can also be used to control the consistency of the potted compound adhesive.

The type and location of the repair will determine the method of adhesive application. For example, a repair on an upper surface would use a low micro-balloon content and would be poured into the cavity, whereas the same repair on an under surface would use a high micro-balloon content and would have to be spooned into the cavity with a spatula or putty knife. Whichever method is used, the adhesive for all repairs should be applied evenly, without trapping any air bubbles.

The type 38 adhesive will set up and bond at room temperature. If a faster bond is required, the repair area should be preheated to 130° F., the repair parts and adhesives applied, and the whole repaired area heated at the same temperature for 1 hr. to effect a complete bond.

Upon completion of the repair, test it for any separation or other flaws, using the metallic ring test.

Core Plug

Core plugs are cut slightly larger than the desired thickness and shape from a glass fabric honeycomb core material ($\frac{3}{16}$-in. cell size). They are sanded to the correct shape and thickness with a belt or disk sander to a tolerance of ±0.010 in. of the required size.

Before a core plug is inserted or assembled into the repair area, all contacting (faying) side surfaces of the core plug and the repair area must be "buttered" with an application of adhesive.

After the core plug has been properly installed into the repair area, the excessive potting compound is removed with a plastic scraper and the surface area thoroughly cleaned with a cleaning solvent. The core plug repair area should be cured for at least 30 min. to 1 hr. This is done to assure that the core plug is firmly in place before any further repair steps are accomplished.

Laminated Glass Cloth Overlay

A laminated glass cloth overlay consists of two layers of glass fabric cloth number 181 (three layers if number 128 is used) impregnated with type 38 adhesive and sandwiched between two sheets of polyethylene film. The glass cloth layers and sheets of polyethylene film are cut larger (approximately 4 in.) than the damage cutout. This is done to accommodate the cutting of the laminated overlay to correct size, allowing for the required minimum overlap of at least 1-½ in. beyond the edge of the damage cutout.

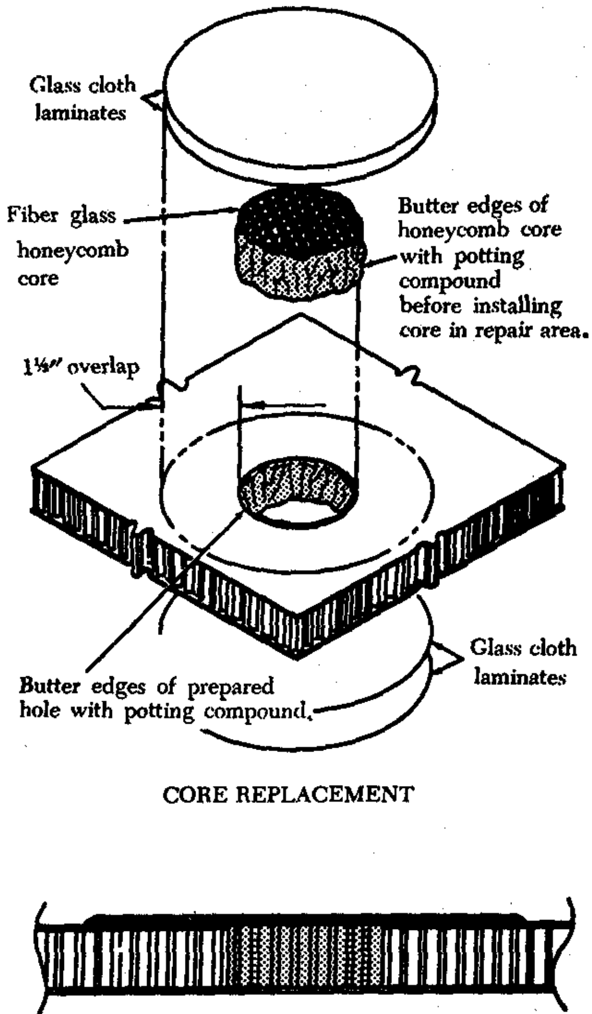
Before a laminated glass cloth overlay is applied to a repair area, the faying surface must be cleaned until no trace of foreign matter appears. After the area has been thoroughly cleaned and dried, a thin and continuous film of adhesive primer EC-776R (or equal) is applied to the faying surfaces of the area. The adhesive primer may be allowed to dry at room temperature or may be accelerated by heat at a recommended temperature.

Protective coatings to prevent erosion and corrosion should be applied in accordance with the procedures outlined in the manufacturer's structural repair manual for the specific aircraft. A control surface repair should be checked to determine whether it is within balance limits or will require the surface to be re-balanced.

ONE SKIN AND CORE REPAIR PROCEDURES

Two typical methods of repairing damages to the honeycomb skin and core materials of aircraft are: (1) Single-face repair with damage extending through the core material and to the bond line of the opposite facing; and (2) transition area repair.

When the damage to the honeycomb structure is inspected and evaluated as damage to only one skin and the core (figure 5-92), the procedures



CORE REPLACEMENT

SECTIONAL VIEW OF REPAIR AREA

FIGURE 5-92. Skin and core repair.

discussed in the following paragraphs can be used. These procedures are typical but may not apply to all types of aircraft. Consult the manufacturer's repair manual for the specific aircraft, and follow the instructions for the particular type of repair.

Removing Damaged Area

A router and the applicable template should be used to remove the damaged material from the area. The depth of the router bit is determined by gradually increasing the depth of cut until it removes all of the damaged area. If the core is only partially damaged, remove only that portion. If the entire core is damaged, remove the core down to the opposite adhesive layer.

Preparing the Core Replacement

The core replacement must be fabricated from fiber glass core material. If the correct thickness is not available, the replacement section may be cut to size by hand sawing and/or sanding. The core plug should be flush or within ± 0.010 in.

Potting Compound

Prepare the potting compound as follows:

(1) Select the desired mix for the repair. A stiff mix is desired when making overhead repairs or for core plug bonding. The average mix or thin mix is desirable when making upper surface repairs.

(2) Add micro-balloons to the resin and mix for 3 to 5 min.

(3) Add the curing agent to the resin and micro-balloon mixture. Mix for 3 to 5 min.

(4) Apply the potting compound to the edges of the core replacement and around the edges of the damaged area in the structure.

Insertion of Core Plug

Place the core plug in the repair area as follows:

(1) Insert the core plug into the repair area.

(2) Remove any excessive potting compound with a plastic scraper and clean the repair area thoroughly.

(3) Allow the core plug repair to cure for at least ½ to 1 hr. at room temperature (72° F) to assure that the core plug is firmly in place.

Application of Glass Cloth Laminates

The preparation for and application of the laminated sections of fiber glass cloth needed to complete the repair should be accomplished as follows:

(1) Remove surface coating from repair area.

(2) Wipe surface with clean cheesecloth moistened with MEK unil no trace of foreign material appears. Do not allow MEK to dry, but wipe it off with a clean cloth.

(3) Apply adhesive primer EC–776R (or equal) with a clean 1-in. varnish brush to faying surface area and allow to dry. Drying time is approximately 1 hr. at room temperature (72° F.). Drying may be speeded by the application of heat not to exceed 150° F. Primer should be applied in a thin and continuous film. Do not thin primer. Primer must be dry for proper adhesion of fiber glass cloth laminates.

(4) Prepare a clean work area, free of all foreign matter. This is generally accomplished by placing a clean piece of paper on a workbench.

(5) Select and cut two sheets of polyethylene film approximately 5 in. larger than the damage cutout.

(6) Prepare two disk templates of thin sheet metal to the correct size of the laminated overlays or 3 in. larger than the damage cutout.

(7) Prepare a batch mix of type 38 adhesive according to the procedures previously discussed in the text.

(8) Place one sheet of polyethylene film on a clean paper-covered work area. The corners of this sheet of polyethylene film may be taped to the work area.

(9) Pour a small amount of type 38 adhesive on this sheet of polyethylene film. With a plastic scraper, spread the adhesive evenly over the sheet of polyethylene film.

(10) Place and center one layer of the glass fabric cloth over the adhesive-covered area of the sheet of polyethylene film.

(11) Pour an adequate amount of type 38 adhesive over the first layer of glass fabric cloth to cover and penetrate its entire area. Spread the adhesive evenly over the area with a plastic scraper.

(12) Apply a second layer of glass fabric cloth in the same manner as the first layer.

(13) Apply a sufficient amount of type 38 adhesive over the second layer of glass fabric cloth in the same manner as over the first layer.

(14) Place and center the second sheet of polyethylene film over the layers of adhesive-impregnated glass fabric cloth.

(15) With a plastic scraper, work out all the air bubbles towards the edges of the laminated overlays. Turn the laminated overlay as necessary in working out the air bubbles.

(16) With a pair of scissors, cut the sandwiched polyethlyene-laminated overlay ½ in. to ¾ in. larger than the actual size of the laminated overlay.

(17) Place and center the sandwiched polyethylene-laminated overlay between the two disk templates that were previously prepared for the repair.

(18) With a pair of scissors, carefully cut the laminated overlay around the edge of the disk templates.

(19) Remove the disk templates from the sandwiched polyethylene-laminated overlay.

(20) Peel off one sheet of polyethylene film from the sandwiched laminated overlay. Discard the polyethylene film.

(21) Place the laminated overlay with the exposed adhesive side down and in position over the repair surface area.

(22) Remove the remaining sheet of polyethylene film from the top side of the laminated overlay. Discard the polyethylene film.

(23) Cut another sheet of polyethylene film ¾ in. to 1 in. larger than the laminated overlay.

(24) Place and center this sheet of polyethylene film over the laminated overlay positioned over the repair surface area.

(25) With a smooth plastic scraper, sweep out any excess resin or air bubbles that may be present within the laminated overlay. This step is of utmost importance to the overall quality of the repair. Therefore, this step should be accomplished with the greatest of care and patience.

(26) Clean the surrounding area of the repair with MEK cleaning solvent. Take care to prevent any of the cleaning solvent from entering the bond of the repair area.

(27) Allow the laminated overlay repair to cure for at least 12 hrs. at room temperature (72° F.) before the final sheet of polyethylene film is removed.

Transition Area Repair

Some bonded honeycomb panels are constructed of a doubler separating an upper and lower skin and sectioned into bays of honeycomb core material. (See figure 5–93.) The edge section of a bay

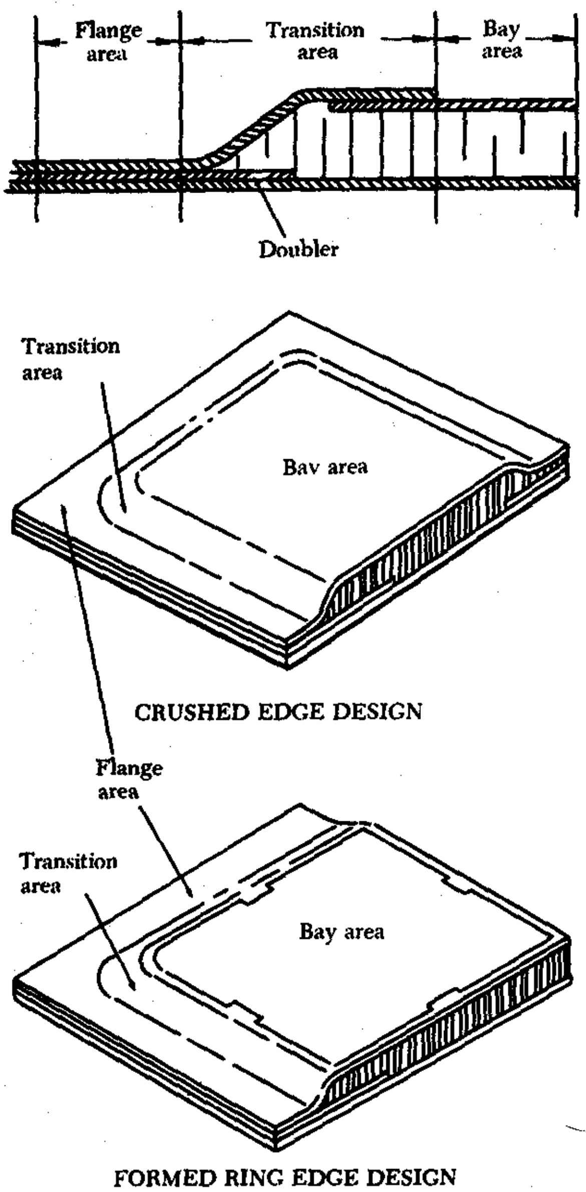


FIGURE 5–93. Typical bonded honeycomb panel bay construction.

area in which the honeycomb structure joins the laminated area of the panel or section is known as the transition area. Effective repairs to the transition areas are particularly essential because of the local transferring of the stresses.

The preparation of the repair materials and the assembly and curing of the core plug are basically the same as for the bonded honeycomb skin and core repairs. However, because of the shape and contour of a transition area, especially at the corners of a bay, give special attention to the cutting and shaping of the glass fabric honeycomb core material.

In this repair, four layers of impregnated glass cloth, number 181, are preferred for the overlays. The preference for glass cloth number 181 is because of its flexibility and ease of application, particularly when making repairs to a corner of a bay where a compound (double) contour is encountered.

Repair Procedures

The steps to be followed in the repair of a transition area are as follows:

(1) Outline the repair to a circular shape (not to exceed 2 in. in diameter) that will encircle the damaged area.

(2) Using a router, remove the damaged area down to the opposite adhesive layer. Depth of the router cut is determined by gradually increasing the depth of the cut until the adhesive layer is reached.

(3) Fabricate a fiber glass honeycomb core to replace the damaged core section. The correct thickness and contour of the transition area may be obtained by hand sawing and/or sanding. The core plug must be shaped to fit flush or within ± 0.010 in.

(4) Prepare the potting compound.

(5) Butter the edges of the fiber glass honey-

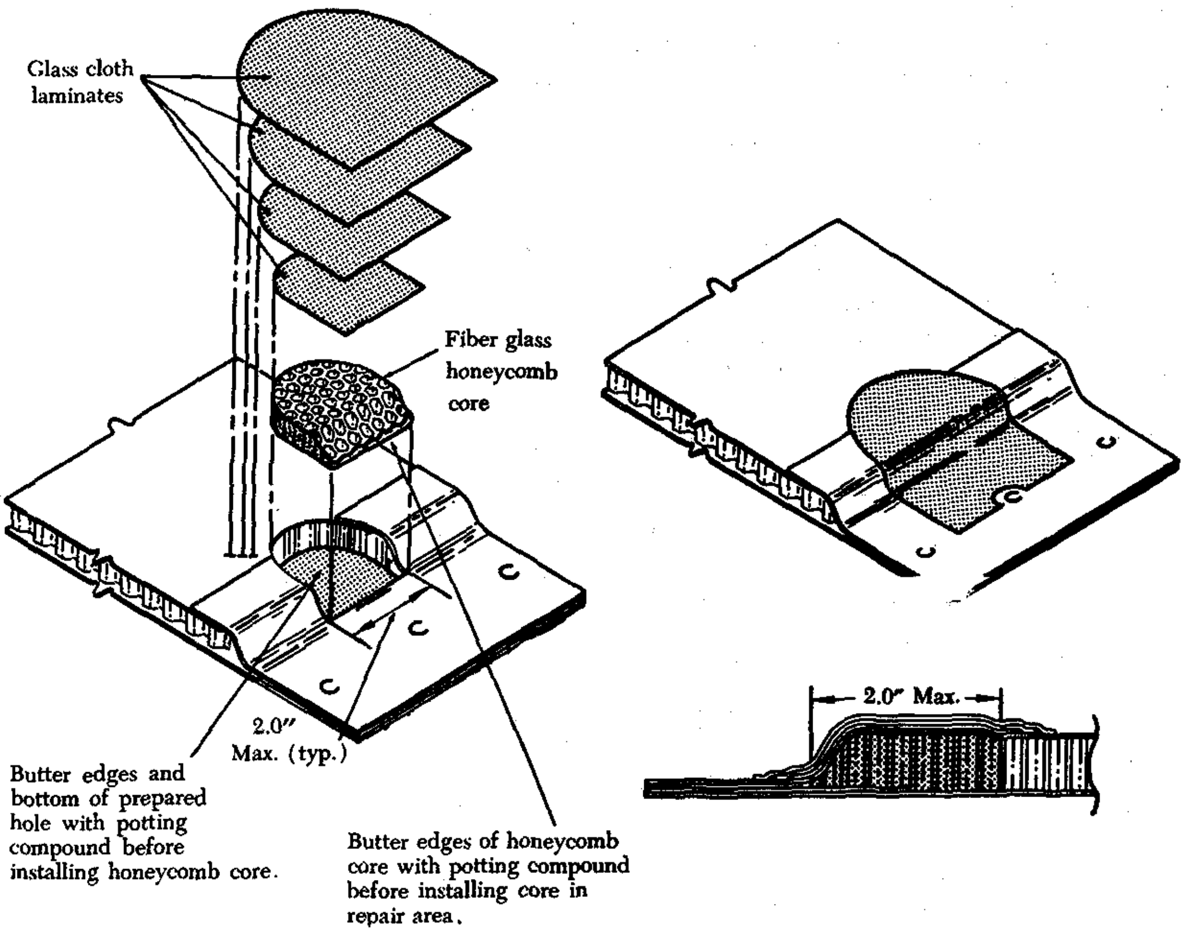


FIGURE 5–94. Transition area repair.

comb core plug with potting compound. (See figure 5-94.)

(6) Install the buttered core plug in the repair area.

(7) Prepare glass fabric adhesive.

(8) Prepare four glass fabric laminates—the first, sufficient in size to adequately cover the damaged area with no overlap; the others, 0.25 in. on all sides. The laminates should not extend over fasteners. If the laminates do extend over fasteners or fastener holes, cut around locations as shown in figure 5-94.

(9) Apply the four glass cloth laminates to the repair area as shown in the section view of the repair illustrated in figure 5-94.

(10) Allow the repair to cure properly.

(11) Apply the necessary erosion and corrosion preventives as specified.

PLASTICS

According to their chemical sources, plastics may be classified into four general groups: (1) Natural resins, (2) synthetic resins, (3) protein plastics, and (4) cellulose plastics.

Natural resins include such materials as shellac, pitch, amber, asphalt, and resin. These materials require fillers when molded.

Synthetic resins are made from petroleum, glycerol, indene, calcium-cyanamide, benzene, urea, ethylene, phenol, and formaldehyde. Products made from synthetic resins include acrylic plastics, nylon, vinyl, styrene, polyethylene, urea-formaldehyde, and others.

Protein plastics are manufactured from a variety of agricultural products. Sources included are peanuts, cashews, milk, coffee beans, and soy beans.

The cellulose plastics are the oldest of the group and include celluloid. Other plastics which fall into this class are acetate, nitrate, ethyl cellulose, butyrate, and propionate.

Nearly all of the early-day plastics were molded. However, today a large percentage of the plastics we know and use are cast, machined, rolled, laminated, or formed by other methods.

TRANSPARENT PLASTICS

Two types of transparent plastics used in aircraft windows, canopies, and similar transparent enclosures are thermoplastic and thermosetting materials.

Thermoplastic materials are originally hard but become soft and pliable when exposed to heat. When pliable, the plastic can be molded; and, as it cools, it will retain the molded shape. When heated again and allowed to cool without being restrained, the plastic will return to its original shape. This process can be repeated many times without damage to the material unless the specified heat ranges are exceeded.

Thermosetting plastics are molded and allowed to cool and set in the desired shape. No amount of reheating will cause them to become pliable and workable. Once formed, they retain that shape and cannot be re-molded or re-shaped.

Each of these types of transparent plastics is available in monolithic or laminated forms. Monolithic plastic sheets are made in single solid uniform sheets. Laminated plastic sheets are made from transparent plastic face sheets bonded by an inner layer of material, usually polyvinyl butyral.

Optical Considerations

Optical qualities of the transparent material used in aircraft enclosures must be as good as those of the best quality plate glass. The ability to locate other aircraft in flight, positive depth perception necessary to land safely, all require a medium which can readily be molded into streamlined shapes and yet remain free from distortion of any kind. Such a medium must also be simple to maintain and repair.

In addition to their ease of fabrication and maintenance, plastics have other characteristics which make them better than glass for use in transparent enclosures. Plastics break in large dull-edged pieces; they have low water absorption and they do not readily fatigue-crack from vibration. But on the other hand, although they are nonconducters of electricity, they become highly electrostatic when polished.

Plastics do not possess the surface hardness of glass, so they are more easily scratched. Since scratches will impair vision, care must be used in servicing an aircraft. Specific procedures to avoid damaging the transparent plastic parts are discussed elsewhere in this chapter. Some general rules to follow are:

(1) Handle transparent plastic materials only with clean cotton gloves.

(2) Never use harmful liquids as cleaning agents, *i.e.*, naphtha, gasoline, etc.

(3) Follow rigidly the applicable instructions for fabrication, repair, installation, and maintenance.

(4) Avoid operations which might scratch or distort the plastic surface. Be careful not to scratch the plastic with finger rings or other sharp objects.

Identification

The identity of transparent plastics used on aircraft can be determined by the MIL specification number on the part. Common MIL numbers and the type of material are as follows (fig. 5–95):

Specifications	*Type Material*	*Edge Color*
Thermoplastic		
MIL-P-6886	Regular Acrylic	Practically clear
MIL-P-5425	Heat Resistant	Practically clear
MIL-P-8184	Craze Resistant	Slightly yellow
Thermosetting		
MIL-P-8257	Polyester	Blue-green
Laminated		
MIL-P-7524	Laminated MIL–P–5425	Practically clear
MIL-P-25374	Laminated MIL–P–8184	Slightly yellow

Base	Name	Distinguishing Features
Acrylate	Plexiglas	Absence of color
	Lucite	Greater transparency
	Perspex (British)	Greater stiffness
Cellulose Acetate	Fibestos	Slightly yellow tint
	Lumarith	Greater flexibility
	Plastacele	Lower transparency
	Nixonite	Softer

FIGURE 5–95. Characteristics of plastics.

If the parts are not marked, the information in the following paragraphs will help to identify the material.

Transparent plastic enclosures and plate glass enclosures can be distinguished from each other by lightly tapping the material with a small blunt instrument. Plastic will resound with a dull or soft sound, whereas plate glass will resound with a metallic sound or ring.

Very few of the transparent plastics are color clear when viewed from the edge; some are practically clear, while others have a slight yellowish tint, or a bluish or blue-green tint.

The cellulose acetate plastics have a yellowish tint when viewed from the edge, and they are softer than the acrylic plastics.

Both acrylic and cellulose acetate base plastics have characteristic odors, especially when heated or burned. Burning a small sample and comparing its odor to that of a known sample is a very reliable method of identification. The acrylic odor is fairly pleasant, but acetate is very repugnant. Acrylic plastic burns with a steady, clear flame, whereas acetate burns with a sputtering flame and dark smoke.

These plastics can also be identified by the application of acetone and zinc chloride. Rub an area of the plastic with a solution of acetone, where it will not interfere with vision. Then blow on the area. If the plastic is acrylic, it will turn white; if it is acetate, it will soften but will not change color. A drop of zinc chloride placed on acetate base plastic will turn the plastic milky, but will have no effect on acrylic plastic.

STORAGE AND PROTECTION

Transparent plastics will soften and deform when heated sufficiently. Therefore, storage areas having high temperatures must be avoided. Plastic sheets should be kept away from heating coils, radiators, or hot water or steam pipes. Storage should be in a cool, dry location away from solvent fumes (such as may exist near paint spray and paint storage areas). Paper-masked transparent plastic sheets should be kept indoors. Direct rays of the sun will accelerate deterioration of the masking paper adhesive, causing it to cling to the plastic so that removal is difficult.

Plastic sheets should be stored, with the masking paper in place, in bins which are tilted at approximately a 10° angle from the vertical to prevent buckling. If it is necessary to store sheets horizontally, care should be taken to prevent chips and dirt from getting between the sheets. Stacks should not be over 18 in. high, and the smaller sheets should be stacked on the larger ones to avoid unsupported overhang.

Masking paper should be left on the plastic sheet as long as possible. Care should be used to avoid scratches and gouges which may be caused by sliding sheets against one another or across rough or dirty tables.

Formed sections should be stored so that they are amply supported and there is no tendency for them to lose their shape. Vertical nesting should be avoided. Protect formed parts from temperatures higher than 49° C. (120° F.). Protection from scratches can be provided by applying a protective coating, *i.e.*, masking paper, untreated builders' paper, posterboard, or similar material.

If masking paper adhesive deteriorates through long or improper storage, making removal of the paper difficult, moisten the paper with aliphatic naphtha. This will loosen the adhesive. Sheets so treated should be washed immediately with clear water.

Aliphatic naphtha is highly volatile and flammable. Use extreme care when applying this solvent.

Do not use gasoline, alcohol, kerosene, benzene, xylene, ketones (including acetone, carbon tetrachloride, fire extinguisher, or deicing fluids), lacquer thinners, aromatic hydrocarbons, ethers, glass cleaning compounds, or other unapproved solvents on transparent acrylic plastics to remove masking paper or other foreign material, because they will soften or craze the plastic surface.

When it is necessary to remove masking paper from the plastic sheet during fabrication, the surface should be re-masked as soon as possible. Either replace the original paper on relatively flat parts, or apply a protective coating on curved parts.

Certain protective spray coatings are available for formed parts. The thickness of the coating should be a minimum of 0.009 in. A layer of cheesecloth should be embedded in the coating at the time of application to assist in the removal of the masking spray. Coatings which remain on formed parts longer than 12 to 18 months become difficult to remove. Under no circumstances should transparent plastic, or formed parts coated with this material, be stored outdoors where it will be subject to direct sunlight for longer than 4 months.

To remove spray masking from the plastic, peel it off or lift a corner of the film and flow a jet of compressed air under it. If the film is too thin to be removed as a continuous film, apply a fresh coating of the compound, reinforced with a layer of cheesecloth, to obtain a thicker film. Allow to dry. Soaking the coated part, using a clean cloth saturated with water at room temperature, will help soften the film so that it can then be peeled off by hand. In no case should a solvent be used.

Extreme care must be used to avoid scratching the surface of the plastic. Tools must never be used in removing the film because of the danger of scratching the plastic.

FORMING PLASTICS

Transparent plastics become soft and pliable when heated to their respective forming temperatures. They can then be formed to almost any shape; and, on cooling, the material retains the shape to which it was formed, except for a small contraction. It is not desirable to cold form compound curvature transparent plastics (that is, to spring them into a curved frame without heating).

Transparent plastics may be cold bent (single curvature) if the material is thin and the radius of curvature to which it is cold bent is at least 180 times the thickness of the sheet. For example, an 18 in. length of transparent plastic, 0.250 in. thick, should not be deflected more than ¾ inch. Cold bending beyond these limits may eventually result in tiny fissures, called crazing, appearing on the surface of the plastic because of stresses being imposed beyond those recommended for continuous loading. For hot forming, transparent plastics should be maintained at the proper temperature recommended by the manufacturer.

Fabricating Processes

The fabrication of transparent plastics can be compared generally to that of wood or soft metal. Good craftsmanship, suitable equipment, and proper design are no less essential to the successful fabrication of transparent plastics than to that of other materials worked by similar methods. Light to medium woodworking equipment with minor modifications is satisfactory, but heavy-duty machines which are less apt to vibrate are better.

Where extreme accuracy is not required, the work can be laid out by penciling the cutting lines directly on the masking paper. For close tolerances, however, it is advisable to scribe layout lines directly on the surface of the plastic. Use straighedges or layout templates according to the requirements of the job. If the masking paper is removed before scribing, it should be replaced to within about ¼ in. of the scribed markings before the piece is cut.

Layout templates may be of plastic sheeting to which suitable handles can be cemented. Sharp edges or rough spots in such templates should be carefully rounded or smoothed. In the case of metal templates, it is good practice to cement thin flannel over the contact surfaces.

Cutting

Scribing and edge sanding is the cutting method most generally used on flat sections or two-dimensional curved pieces. The sheet is first cut to approximate shape on a band saw, using a scribed line as a guide and cutting approximately $\frac{1}{16}$ in. oversize. Use disk sanders when removing material from straightedges and outside curves. Use drum or belt sanders for inside curved edges. When sanding irregular shapes or larger pieces which are awkward to manipulate around a fixed machine, use an air-driven sander or small electric hand sander.

Drilling

For the sake of both accuracy and safety, hold work in suitably designed clamps or fixtures. The twist drills commonly used for soft metals can be used successfully for transparent plastics if ordinary care is observed. However, the best results can be obtained if drills are re-pointed with the following in mind:

(1) The drill should be carefully ground free of nicks and burrs which would affect surface finish.

(2) It is particularly important that the cutting edge be dubbed off to zero rake angle.

(3) The length of the cutting edge (and hence the width of the lip) can be reduced by increasing the included angle of the drill. (See figure 5–96.)

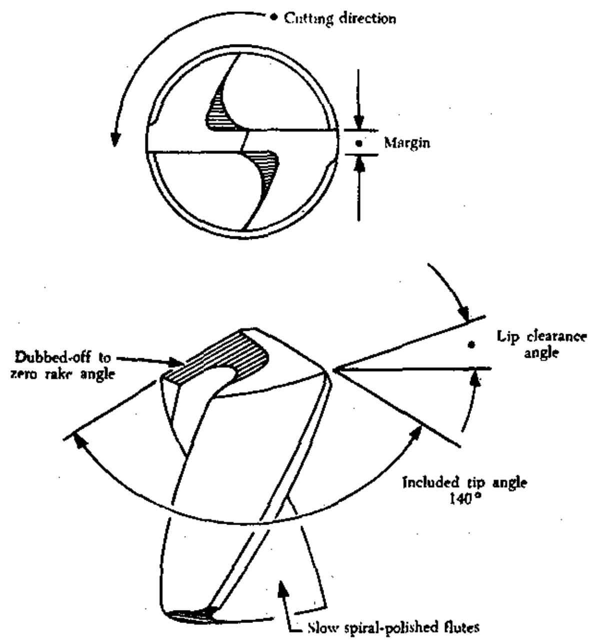


FIGURE 5–96. Drill for acrylic plastics.

Use drills with slow-spiral polished flutes. Flutes should be as wide as possible. The best lubricant and coolant for drilling plastics is a water-soluble cutting oil. For drilling shallow or medium depth holes, no coolant is needed. For deep holes, of course, a coolant is necessary.

Cleaner, more transparent deep holes can be produced by first drilling a pilot hole a little more than half the diameter of the final hole, filling this pilot hole with a wax stick, then redrilling to the final diameter. If the pilot hole is drilled all the way through, the Plexiglas must be backed with wood to close the hole and make the wax stick effective. The wax lubricates the cut and supports and expels the chips during drilling. In clear Plexiglas the resulting hole is cleaner, smoother, and more transparent than holes produced by other methods.

Large diameter holes can be cut with hollow-end mills, hole saws, fly cutters or trepanning tools. The cutters of the latter should be ground to zero rake angle and adequate back clearance, just as lathe tools are ground. All these tools can be used in the standard vertical spindle drill press or in flexible shaft or portable hand drills.

In general, the speed at which Plexiglas sheets can be drilled depends largely on the quality of the equipment used. Plexiglas can be drilled at the highest speed at which the drill will not "wobble" sufficiently to affect the finish of the hole. However, large diameter drills require slower rotative speeds for best results. Also, the Plexiglas should be backed with wood and the feed slowed as the drill point breaks through the underside of the sheet.

Whenever holes are drilled completely through Plexiglas, the standard twist drills should be modified to a 60° tip angle, the cutting edge to a zero rake angle, and the back lip clearance angle increased to 12–15°.

Drills specially modified for drilling Plexiglas are available from authorized distributors and dealers of Plexiglas.

For accuracy and safety, Plexiglas parts should be clamped or held rigidly during drilling.

SHALLOW HOLES—Hole depth/ hole diameter ratio of less than $1\frac{1}{2}$ to 1, use slow spiral twist drills with wide flutes modified as for through drilling. Chip removal is no problem in drilling shallow holes and no coolant is needed.

MEDIUM DEEP HOLES—Hole depth/hole diameter ratio from $1\frac{1}{2}$ to 1 up to 3 to 1.

Use slow spiral twist drills with polished flutes which should be as wide as possible to aid in removing a continuous ribbon of material. The optimum included tip angle, between 60° and 140°, will depend on the size of the flute. Lip clearance angles should be ground to 12° to 15°. The feed of the drill should be controlled so that a continuous chip is cut and cleared without overheating the plastic at the tip of the drill. No coolant is needed for drilling holes up to 3 to 1 depth/diameter ratios although a jet of compressed air directed into the hole as it is being drilled is helpful. Drills with extra wide spirals and compressed air cooling can clear a continuous chip from holes with depth/diameter ratios up to 5 to 1.

DEEP HOLES—Hole depth/hole diameter ratio greater than 3 to 1.

Use slow spiral twist drills with wide polished flutes and an included tip angle of 140°. The wider tip angle results in a shorter cutting edge and narrow chip. The lip clearance angle should be ground to 12° to 15°. The feed should be slow—approximately 2½″ per minute—so that powder, rather than shavings or continuous chips, will be formed. A coolant is necessary for drilling deep holes to avoid scoring or burning the surface of the hole.

Compressed air can be used as a coolant for holes with depth diameter ratios up to 5 to 1. Water or a soluble oil-water coolant can also be used. When applied at the entry hole, however, a liquid coolant is actually pumped out of the hole by the drill and seldom reaches the drill point. A standard oil hole drill can be used to insure delivery of the coolant to the drill point. The collant can also be applied by filling a pilot hole drilled 95% of the way through the material or through a pilot hole drilled through from the opposite surface.

Cementing

With care and proper procedure, it is possible to obtain a cemented joint which approximates the original plastic in strength. Cementing of transparent acrylic plastics depends on the intermingling of the two surfaces of the joint so that actual cohesion exists. To effect cohesion, an organic liquid solvent is used to attack the plastic, forming a well-defined soft surface layer called a cushion, as shown in figure 5–97.

The most common method of cementing transparent plastics is the "soak method." This consists of dipping one of the two pieces to be cemented into the cement until a sufficient cushion is formed. When this surface is pressed against the opposite dry surface, the excess cement forms a second cushion—shallow, but enough to permit thorough intermingling of the two surfaces, as shown in figure 5–97.

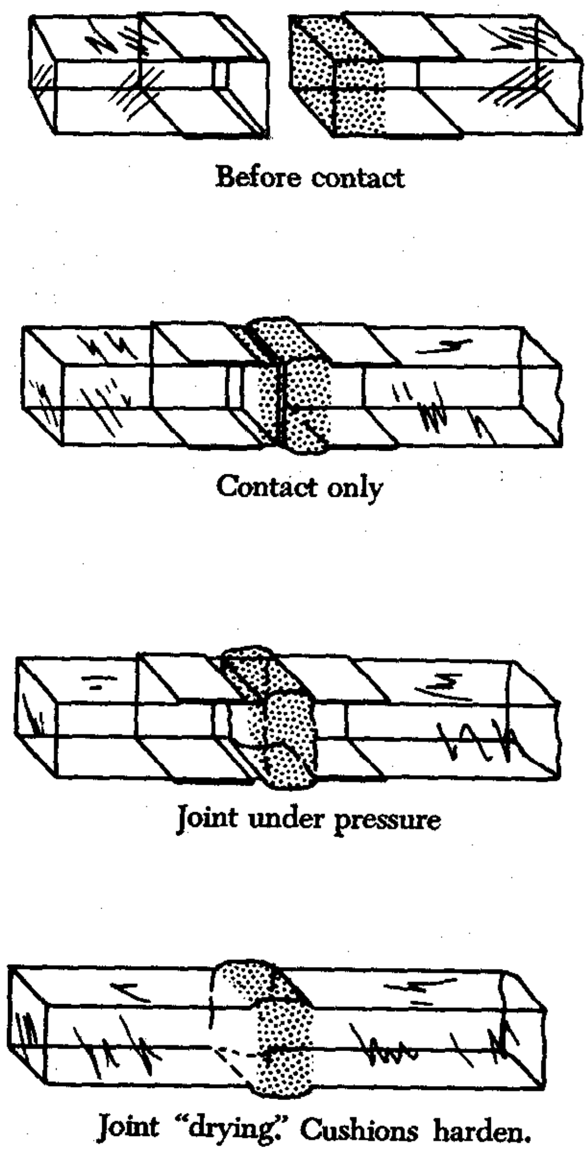


FIGURE 5–97. Cementing with solvent cement.

Sometimes, for convenience in handling, clear transparent plastic shavings of the same type as the transparent plastic being cemented are dissolved in the cement to give it a thick, syrupy consistency so that it can be applied like glue. This viscous cement, however, works on exactly the same principle as a soak cement; for example, the excess solvent softens and swells both surfaces, permitting an intermingling of the cushions and the formation of a cohesive bond as shown in figure 5–98.

A solvent joint never dries completely; that is, it will never become entirely free of solvent. If the temperature is raised, the cushion will enlarge

slowly until a new equilibrium is reached, as shown in figure 5–99.

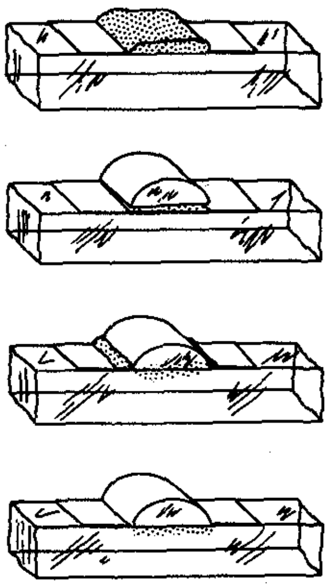


FIGURE 5–98. Cementing with syrup cement.

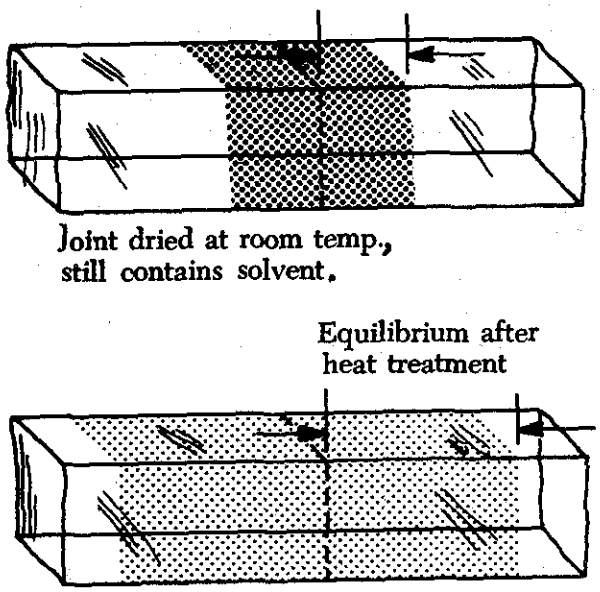


FIGURE 5–99. Effect of heat treatment.

On cooling, the cushion will be larger and correspondingly harder since it contains less solvent per unit of volume. Heating a solvent joint long enough to expand its cushion, therefore, will produce a much stronger joint.

Cemented joints must be heat treated with caution. Heat first activates the solvent, which softens the cushion. The cushion then slowly expands as the solvent penetrates the material. In heat treating, it is important that the temperature does not approach the softening point of transparent plastics.

It is important that the joint be thoroughly hardened before machining, sanding, or polishing to remove the bead.

Care and Maintenance

Vision is so vital in aircraft that day-to-day maintenance of transparent enclosures is of the utmost importance. Proper maintenance methods should be carried out thoroughly whenever vision is impaired as a result of chemical or physical actions or defects, and every effort should be put forth to eliminate harmful action while servicing the aircraft.

The replacement of transparent plastic enclosures has been necessitated by severe crazing, apparently caused by exposure to harmful solvents and improper maintenance handling. The crazing appears as a network of cracks running in all directions over the surface of the plastic. It can also occur within the plastic at or near cemented joints.

The use of improper cleaning fluids or compounds is one of the most common causes of these difficulties. The crazing action of a solvent is often delayed; that is, crazing may not appear for several weeks after the exposure to solvent or fumes. It is not always possible to determine immediately, by simple trial, whether a particular cleaner will be injurious or not. To minimize the damage, the precautions discussed in the following paragraphs should be observed.

Routine removal of film and other operational soils, where abrasive polishing for scratch removal is not required, can be accomplished by the use of aqueous detergent solutions. Two recommended solutions are: wetting agent, synthetic, nonionic, conforming to Military Specification MIL-D-16791; or wetting agent, alkyl aryl sulfonate, 40% active. These materials should be used in concentrations of 2 or 3 oz. per gal. of water. They should be applied with soft cloths or photographic cellulose sponges which have been used for no other purpose. Polish and cleaner conforming to Military Specification MIL–C–18767 will give satisfactory results for most cleaning requirements.

When cleaning exterior surfaces, always remove rings from the hands before washing the transparent plastic. The cleaning procedure is comprised of the following steps:

(1) Flush the plastic surface with plenty of water, using the bare hands to feel for and gently dislodge any dirt, sand, or mud.

(2) Wash with mild soap and water. Be sure the water is free of harmful abrasives. A soft cloth, sponge, or chamois may be used in washing, but only to carry the soapy water to the plastic. Go over the surface with bare hands to quickly detect and remove any remaining dirt before it scratches the plastic.

(3) Dry with a damp clean chamois, a clean soft cloth, or soft tissue. Do not continue rubbing the transparent plastic after it is dry. This not only scratches, but may build up an electrostatic charge which attracts dust particles. If the surface becomes charged, patting or gently blotting with a clean damp chamois will remove the charge as well as the dust.

(4) Never use a coarse or rough cloth for polishing. Cheesecloth is not acceptable.

The procedure for cleaning interior surfaces consists of three steps:

(1) Dust the plastic surface lightly with a clean soft cloth saturated with clean water. Do not use a dry cloth.

(2) Wipe carefully with a damp soft cloth or sponge. Keep the cloth or sponge free from grit by rinsing it frequently with clean water.

(3) Clean with an approved cleaner.

In hot weather the transparent enclosures of parked aircraft may absorb enough heat to soften and become distorted unless certain precautions are taken. Plastic enclosures installed on aircraft parked in the sun may receive heat directly from three sources.

Transparent plastic has a property of absorbing, selectively, the heat producing rays of the sun so that the platsic can become considerably hotter than the surrounding air inside or outside the aircraft.

Air inside an unshaded and unventilated aircraft will transfer the heat radiated by the metal members in the aircraft to the plastic enclosure by convection.

To prevent heat deformation of transparent plastic enclosures on aircraft parked exposed to the sun, the following precautions are recommended:

(1) If surrounding air temperature is below 100° F., no special precautions are necessary.

(2) If surrounding air temperature is between 100° and 120° F., enclosures should be opened sufficiently to permit free circulation of air through the aircraft and under the enclosure.

(3) If the surrounding air temperature is above 120° F., the enclosure must be opened and protected from the sun by a suitable cover which does not come into contact with the transparent plastic. If possible, the aircraft should be parked in the shade.

(4) To remove enclosure covers, lift them off; sliding may cause abrasion of the plastic surfaces.

Compounds for paint stripping, degreasing, and brightening, as well as most organic solvents, cause serious damage to transparent acrylic plastics. All such parts should be removed before starting paint stripping, and should not be replaced until the cleaning and painting is completed and the paint or lacquer is thoroughly dry, since paint and lacquer cause crazing of plastics. The plastic parts should be removed from the area where the stripping, degreasing, or painting is being done. The parts should be protected with soft cloth covers.

If it is impracticable to remove a plastic panel, cut a polyethylene sheet (minimum of 0.010-in. thick and containing no pinholes) to match as exactly as possible the size of the window. The polyethylene sheet should fit snugly over the surface of the plastic window, and the edges should be carefully taped with masking tape at least 2 in. wide to permit at least 1 in. of sealing width on both the plastic film and the aircraft. Make certain that no liquid or fumes can seep through to the window. It is important that the entire surface of the window be covered and that no cutting tools be used to remove the masking.

Aluminum foil is unsatisfactory as a protection from paint (and other sprays which contain solvents) because of its low resistance to tears, punctures, and pinholes. Protective coating conforming to Military Specification MIL-C-6799 is satisfactory as a protection from paint and other sprays which contain solvents.

Do not sand transparent plastics unless it is absolutely necessary. Hairline scratches of 0.001-in. maximum depth should be left as is, provided optical requirements are maintained.

INSTALLATION PROCEDURES

There are a number of methods for intalling transparent plastic panels in aircraft. The method the aircraft manufacturer utilizes depends on the position of the panel on the aircraft, the stresses to which it will be subjected, and a number of other factors. When installing a replacement panel, follow the same mounting method used by the aircraft manufacturer.

Where difficulty is encountered in rivet installation, bolts may be substituted when installing replacement panels, provided the manufacturer's original strength requirements are met and the bolts do not interfere with adjoining equipment.

In some instances replacement panels do not fit the installation exactly. Whenever adjustment of a replacement panel is necessary, the original design drawing, if available, should be consulted for proper clearances. The following principles should be considered in installing all replacement panels.

Fitting and handling should be done with masking material in place. Do not scribe plastic through masking material. On edges where transparent materials will be covered, or attached to, remove the masking material. When subject to large stresses, transparent plastics are apt to craze. It is of prime importance that plastics be mounted and installed so that such stresses are avoided.

Since transparent plastic is brittle at low temperatures, extra care must be taken to prevent cracking during maintenance operations. Transparent plastic parts should be installed at room temperature, if practicable.

Never force a transparent panel out of shape to make it fit a frame. If a replacement does not fit easily into the mounting, obtain a new replacement or sand the panel sufficiently to obtain the exact size that conforms with the mounting frame.

Do not heat and re-form areas of the panel, since local heating methods are likely to be only superficial and not thorough enough to reduce stress concentrations.

Since plastics expand and contract approximately three times as much as metal, suitable allowance for dimensional changes with temperature must be made. Use the values shown in figure 5–100 as minimum clearances between the frames and the plastics.

Dimension of Panel in Inches **	Dimensional Allowance in Inches *	
	Required for Expansion from 25°C (77°F) to 70°C (158°F)	Required for Contraction from 25°C (77°F) to −55°C (−67°F)
12	0.031	0.050
24	0.062	0.100
36	0.093	0.150
48	0.124	0.200
60	0.155	0.250
72	0.186	0.300

* Where the configuration of a curved part is such as to take up dimensional changes by change of contour, the allowances given may be reduced if it will not result in localized stress. Installations permitting linear change at both ends require half the listed clearances.

** For dimensions other than those given use proportional clearance.

FIGURE 5–100. Expansion and contraction allowances.

Bolt and Rivet Mountings

In bolt installations, spacers, collars, shoulders, or stop nuts should be used to prevent excessive tightening of the bolt. Whenever such devices are used by the aircraft manufacturer, they should be retained in the replacement installations.

To ensure long service, give special consideration to the following factors:

(1) Use as many bolts or rivets as practical.
(2) Distribute the total stresses as equally as possible along the bolts and rivets.
(3) Make sure the holes drilled in the plastic are sufficiently larger than the diameter of the bolt to permit expansion and contraction of the plastic relative to the frame.
(4) Make sure the holes in the plastic are concentric with the holes in the frame so that the greater relative expansion of the plastic will not cause binding at one edge of the hole. The hole should be smooth and free of any nicks or roughness.
(5) Use oversize tube spacers, shoulder bolts, rivets, cap nuts, or some other device to protect the plastic from direct pressure.

Synthetic Fiber Edge Attachment

Modern edge attachments to transparent plastic assemblies are made of synthetic fibers specially impregnated with plastic resins. The most commonly used fibers are glass, orlon, nylon, and dacron.

Reinforced laminated edge attachments are the preferred type, especially when mounting by bolts or rivets is necessary. The edges have the advantage of more efficiently distributing the load and reducing failures caused by differential thermal expansion.

Laminated edge attachments can be mounted by any of the foregoing methods, with any needed holes drilled through the edge attachment material and not the transparent plastic.

The most efficient method of mounting a laminated edge attachment is by the "slotted hole" method. The slotted holes are in the edge attachment and allow for differential thermal expansion.

Fabric loop attachments are sometimes attached to the plastic material with a cable or extrusion contained within the loop. A special extrusion is necessary to contain the loop and cable.

LAMINATED PLASTICS

Laminated plastic enclosures are made by bonding two layers of monolithic transparent sheets together with a soft plastic inner layer. They are installed in pressurized aircraft because of their superior shatter resistance and greater resistance to explosive decompression as compared to monolithic plastic enclosures.

Cellulose Acetate Base Plastics

In general, the methods used for fabrication, repair, and maintenance of cellulose acetate base plastics are similar to those used for acrylic plastics. In handling cellulose acetate base plastics, give attention to the following variations and additions to the recommendations already given for acrylic plastics.

Since the chemical composition of acetate base plastics differs greatly from that of acrylics, the cement used is of a different type. Generally, two types are used, solvent and dope.

Solvent type cement is generally used where transparency must be maintained in the joint. It is relatively quick drying and is well adapted for use in making emergency repairs. However, even though the cement is quick drying, the drying time will vary with the size of the joint and atmospheric conditions. Acetone may be used as a solvent type cement.

Dope type cement is preferred for use where the surfaces to be joined do not conform exactly. This cement softens the surfaces of a joint and, at the same time, creates a layer between the two pieces being cemented. However, it does not give a transparent joint and is slower drying than the solvent cement. It will take from 12 to 24 hrs. for the joint to reach full strength.

Since the expansion and contraction rates of acetate-base plastics are greater than those of acrylics, make greater allowances when mounting them. These plastics are affected by moisture and will swell as they absorb water. In general, allow ⅛ in. per foot of panel length for expansion, and $\frac{3}{16}$ in. per foot for contraction.

FIBER GLASS COMPONENTS

Because of the unequaled strength/weight ratio, the ability to pass radio and radar waves, the ease of manufacture in contoured shapes, immunity to mildew and weather resistant characteristics, and adaptability to numerous places and shapes, fiber glass is a versatile material with numerous uses in modern aircraft construction. A few of the many applications are radomes, radio antenna covers, and junction boxes.

Fiber glass is manufactured from specially processed glass balls. By a fabrication process, the glass is turned into fibers which may result in an end product of cloth, molded mats, or yarn. The yarn is used to manufacture molded parts. The fiber glass cloth is used in making laminated shapes or in the repair of laminated assemblies. Another use is in the repair of metal structures.

Mat Molded Parts

Nonstructural parts, such as junction boxes, heater ducts, relay shields, and other electrical applications, are manufactured from mat-molded fiber glass. Molded mat fiber glass is short chopped fibers molded in a mat form. The assemblies are fabricated by a process wherein the chopped fibers are molded around a form, bonded together by use of a resin, and cured while under heat and pressure.

Carelessness in removing or handling mat-molded parts can cause the assembly to become damaged. Vibration may be another factor in the cause of cracks in the assemblies. Damage to mat-molded parts usually consists of holes or cracks (figure 5–101). Similar repair procedures are used for either type of damage.

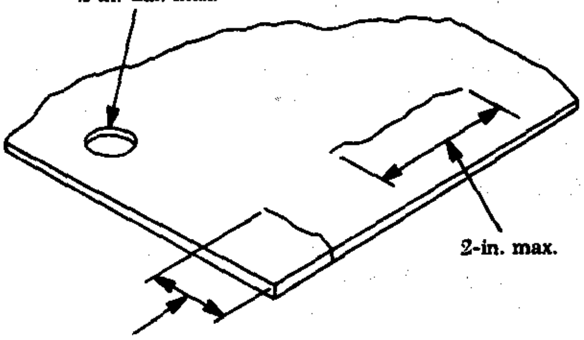


FIGURE 5–101. Typical damage to mat molded parts.

Repair Procedures

The following procedures are typical of those used in the repair of a mat-molded assembly. However, they are not to be construed as the only procedures that could be used. The correct section of the structural repair manual for the specific aircraft should be consulted and followed in all situations.

(1) Inspect the part for location of the crack.

(2) Remove the paint or protective coating from around the damaged area.

(3) Stop-drill the end of the crack. The size of the twist drill should be not smaller than ⅛ in. and not larger than $^3/_{16}$ in.

(4) Lay out and sand the damaged area to the dimensions given in figure 5–102. Remove one-third of the material from both sides of the damaged area. Bevel the area 15° to 45°, as shown in figure 5–102, and sand ½ in. beyond the beveled area.

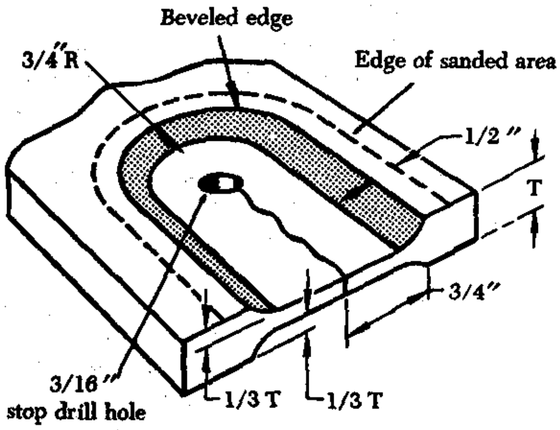


FIGURE 5–102. Mat molded repair.

(5) Prepare two pieces of PVA (polyvinyl alcohol) film large enough to cover the repair area.

(6) Prepare two pieces of metal large enough to cover the area. Use any piece of metal that will provide satisfactory holding strength.

(7) Check and start the air-circulating furnace. Set the temperature regulator at 220° F.

(8) Select and prepare the resin mixture.

(9) Cut the mat fiber glass material and saturate it in the prepared resin. Cut enough pieces of material to build up the beveled out area to its original contour.

(10) Insert the saturated mat fiber glass material into the repair area. (See figure 5–103.)

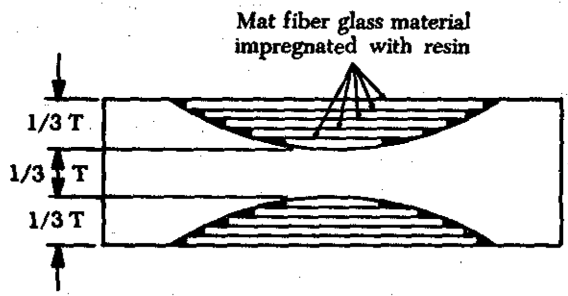


FIGURE 5–103. Insertion of precut saturated sections.

(a) Do one side at a time.
(b) Cover each side with the precut PVA film.
(c) Place the prepared metal plate on each side of the repair as it is completed.
(d) Secure the repair in place by use of C-clamps.

(11) Place the assembly in the preheated oven for at least 1 hr. (check applicable or manufacturer's instructions for the resin used).
(12) Remove the assembly from the oven and let it cool at room temperature.
(13) Disassemble the repair, removing C-clamps, metal plates, and PVA film.
(14) Sand both sides to a smooth finish and to the original contour of the part.
(15) Inspect the repair for soundness, using a metallic ring test. A good repair, when struck with a coin or light aluminum hammer, should resound with a metallic ring.

RADOMES

The protective dome or domelike covering for a radar antenna or other radar equipment is called a radome. It must be able to withstand the effects of hail, icing, wind, temperature changes, static electricity, supersonic speeds, and stratospheric altitudes. Also, it must have excellent dielectric qualities.

Handling, Installation, and Storage

Caution should always be used when handling, installing, or storing aircraft radomes. The necessity for the utmost care to prevent damage to sandwich parts cannot be overemphasized. Radomes (radar and radio antenna housings) are especially susceptible to damage. Damage is sometimes minute and invisible, but when exposed to vibration, stress, or liquids (water or oil), deterioration follows. Microwave distortion and energy losses occur as a result of cracks, punctures, and other physical damage, including moisture and oil contamination.

Take care also to avoid contamination with paint removers and stripping compounds normally used on the metal parts of the aircraft for removing finishes. Some of these materials have been found to penetrate the plastic facings of the radome and may have an adverse effect on its electric properties or its strength. Mild soap and water are used for general cleaning of radome surfaces. When a solvent cleaner is required for removing oils and greases on radome surfaces, use a clean cloth dampened with MEK.

Radomes must be handled with special care. Placing radomes upon rough surfaces and among metal parts must be avoided. Caution should always be used to avoid radome damage resulting from the radome striking against work stands, being dropped, or being drug across rough surfaces.

Correct radome installation begins with the uncrating procedure. Before uncrating a radome, provide a clean padded surface at least as large as that which the radome will occupy when uncrated. Adhere closely to the instructions for opening the radome crate. This will prevent damages that would be inflicted to the radome by protruding nails, bolts, staples, or other sharp objects. Installation instructions outlined in the applicable aircraft maintenance manual must be followed closely when installing radomes. Should sanding or grinding of the radome be required to fit a mounting frame, the sanded surfaces should be classified as a class I repair (discussed later in this chapter) and reworked accordingly.

Radomes should be stored where they are not subject to high humidity. They should be stored in suitable crates or padded racks and supported from the mounting holes. Avoid stacking radomes directly upon each other.

Detection and Removal of Oil and Moisture

All radomes are susceptible to moisture and oil contamination. Either can be the cause of very serious degradation of the performance of the aircraft's radar system. Contamination also causes weakening of the radome facing and the facing-to-core bonding strength.

Radomes should be inspected for moisture or oil containmination prior to repairing or identifying as serviceable; they must be clean and dry prior to electrical testing. Radomes can be checked for moisture pockets using an electronic moisture meter. The probe unit of the meter should be held in contact with the inner surface of the radome and slowly moved over the surface. The presence of moisture will be indicated on the calibrated meter dial. Moisture detection and removal procedures should be accomplished on all radomes before performing repairs.

Inspection For Damage

Radomes should be visually inspected for delaminations, scars, scratches, or erosion of the protective coating that would affect only the outer ply. They should be inspected also for punctures, contamination, fractures of plies affecting either the plies on one side, the plies and core material, or damage extending completely through the outer plies, core material, and inner plies. Different aircraft have different limitations on damage that is reparable, the type of repairs allowed and on damage that is nonreparable. This information can usually be found in the maintenance manuals for the specific aircraft.

Damages to sandwich parts are divided into groups or classes according to the severity and possible effect upon the structure of the aircraft and upon electrical efficiency. Damages are classified in three basic classes: (1) Class I repairs—scars, scratches, or erosion affecting the outer ply only; (2) class II repairs—punctures, delaminations, contaminations, or fractures in one facing only, possibly accompanied by damage to the core; and (3) class III repairs—damage extending completely through the sandwich affecting both the facings and the core.

Radome Repairs

Repair procedures are developed with the objective of equaling as nearly as possible the electrical and strength properties of the original part with a minimum of increase in weight. This can be accomplished by repairing damaged parts with approved materials and working techniques. Therefore radome repairs should be accomplished in accordance with manufacturer's procedures by specially trained personnel of a shop which has proper facilities and adequate test equipment to ensure a satisfactory repair.

Testing of Repairs

Radomes must be repaired in a manner that will ensure not only the structural integrity of the radome, but the electrical characteristics as well. The type of electrical test required after a repair is completed depends on the purpose for which the radome was designed. Typical of the type of electrical tests conducted are:

(1) Transmissivity, which is the average one-way power transmission through the radome or the ratio of power transmitted through the radome to the same power transmitted with the radome removed.

(2) Incidence reflection, the power reflected into the radar system by the radome.

(3) Deflection or refraction to check for possible ghosts or false target returns.

WOODEN AIRCRAFT STRUCTURES

While the trend is undoubtedly toward all-metal aircraft, many airplanes still exist in which wood was used as the structural material. The inspection and repair of these wooden structures will continue to be the responsibility of the airframe mechanic. The ability to inspect wood structures and recognize defects such as dry rot, compression failures, etc., must be developed.

The information in this section is of a general nature and should not be regarded as a substitute for specific instructions contained in the aircraft manufacturer's maintenance and repair manuals. Methods of construction vary with different types of aircraft, as will the various repair and maintenance procedures.

INSPECTION OF WOODEN STRUCTURES

Whenever possible, the aircraft should be kept in a dry, well-ventilated hangar with all inspection covers, access panels, etc., removed for as long as possible prior to inspection. If the aircraft is thoroughly dried out, this will facilitate the inspection, especially when determining the condition of glued joints.

Before beginning a detailed inspection of the glued joints and the wood, a rough assessment of the general condition of the structure can sometimes be obtained from the external condition of the aircraft.

The wings, fuselage, and empennage should be checked for undulation, warping or any other departures from the original shape. In instances where the wings, fuselage, or empennage structures and skins form stressed structures (figure 5–104), no departure from the original contour or shape is permissible.

Where light structures using single plywood covering are concerned, some slight sectional undulation or bulging between panels may be permissible provided the wood and glue are sound. However, where such conditions exist, a careful check must be made of the attachment of the ply to its supporting structure. A typical example of a distorted single plywood structure is illustrated in figure 5–105.

The contours and alignment of leading and trailing edges are of particular importance, and a careful check should be made for departure from the original shape. Any distortion of these light ply-

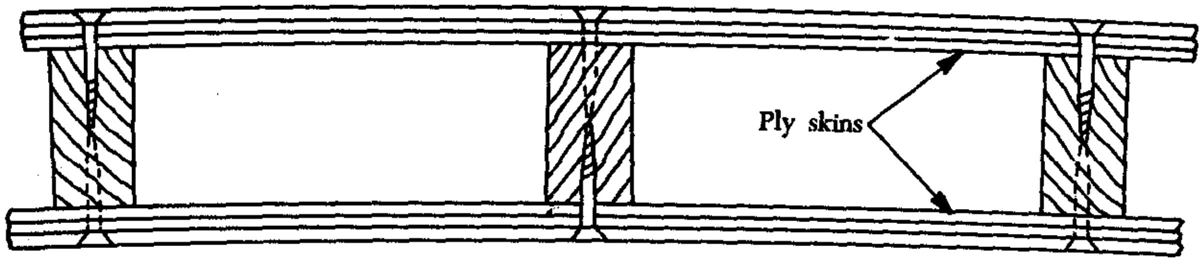


FIGURE 5–104. Cross sectional view of a stressed-skin structure.

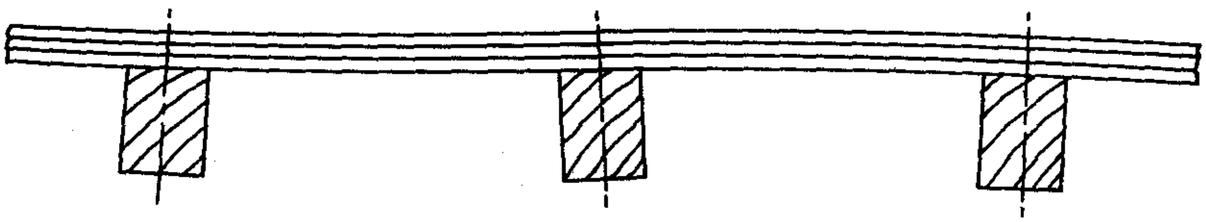


FIGURE 5–105. Single ply structure.

wood and spruce structures is indicative of deterioration, and careful internal inspection will have to be made for security of these parts to the main wing structure, and for general deterioration of the light plywood and spruce members. If deterioration is found in these components, the main wing structure may also be affected.

Splits in the fabric covering on plywood surfaces should not be repaired by doping on another piece of fabric over the affected area. In all cases, the defective fabric should be removed to ascertain whether the plywood skin beneath is serviceable, since it is common for a split in the plywood skin to be responsible for initiating a similar defect in the protective fabric covering.

Although a preliminary inspection of the external structure can be useful in assessing the general condition of the aircraft, it should be noted that wood and glue deterioration can often take place inside a structure without any external indications. Where moisture can enter a structure, it will seek the lowest point where it will stagnate and promote rapid deterioration. It should also be noted that glue deterioration can take place through other causes without the presence of water.

Glue failure and wood deterioration are often closely allied, and the inspection of glued joints must include an examination of the adjacent wood structure.

The inspection of a complete aircraft for glue or wood deterioration will necessitate checks on parts of the structure which may be known or suspected trouble spots and which are, in many instances, boxed in or otherwise inaccessible. In such instances, considerable dismantling is required, and it may be necessary to cut access holes in ply structures to facilitate the inspection. Such work must be done only in accordance with approved drawings or the repair manual for the aircraft concerned.

Glued Joint Inspection

The inspection of glued joints in aircraft structures presents considerable difficulties. Even where access to the joint exists, it is still difficult to positively assess the integrity of the joint. Keep this in mind when inspecting wooden structures.

Some of the more common factors which may cause glue deterioration are: (1) Chemical reactions of the glue caused by aging or moisture, extreme temperatures, or a combination of these factors, (2) mechanical forces caused mainly by wood shrinkage, and (3) development of fungus growths.

Aircraft exposed to large cyclic changes of temperature and humidity are especially prone to wood shrinkage which may lead to glue deterioration. The amount of movement of wooden members due to these changes varies with the size of each member, the rate of growth of the tree from which the wood was cut and the way in which the wood was converted. Thus, two major members in an aircraft structure, secured to each other by glue, are unlikely to have identical characteristics. Differential loads will, therefore, be transmitted across the glue film since the two members will not react in an identical manner relative to each other. This will impose stresses in the glued joint which can normally be accommodated when the aircraft is new and for some years afterwards. However, glue tends to deteriorate with age, and stresses at the glued joints may cause failure of the joints. This is true even when the aircraft is maintained under ideal conditions.

When checking a glue line (the edge of the glued joint) for condition, all protective coatings of paint should be removed by careful scraping. It is important to ensure that the wood is not damaged during the scraping operation. Scraping should cease immediately when the wood is revealed in its natural state and the glue line is clearly discernible.

The glue line is often inspected by the use of a magnifying glass. Where the glue line tends to part or where the presence of glue cannot be detected or is suspect, the glue line should be probed with a thin feeler gage. If any penetration is possible, the joint should be regarded as defective. It is important to ensure that the surrounding wood is dry; otherwise, a false impression of the glue line would be obtained due to closing of the joint by swelling. In instances where pressure is exerted on a joint, either by the surrounding structure or by metal attachment devices such as bolts or screws, a false impression of the glue condition could be obtained unless the joint is relieved of this pressure before the glue line inspection is carried out.

The choice of feeler gage thickness will vary with the type of structure, but a rough guide is that the thinnest possible gage should be used. Figure 5–106 indicates the points where checks with a feeler gage should be made.

Wood Condition

Dry rot and wood decay are not usually difficult to detect. Dry rot is indicated by small patches of crumbling wood. A dark discoloration of the wood surface or gray stains running along the grain are indicative of water penetration. If such discoloration cannot be removed by light scraping, the part should be replaced. Local staining of the wood by the dye from a synthetic adhesive hardener can be disregarded.

In some instances where water penetration is suspected, the removal of a few screws from the area in question will reveal, by their degree of corrosion, the condition of the surrounding joint (figure 5–107).

The adhesive will cause slight corrosion of the screw following the original construction; therefore, the condition of the screw should be compared with that of a similar screw removed from another

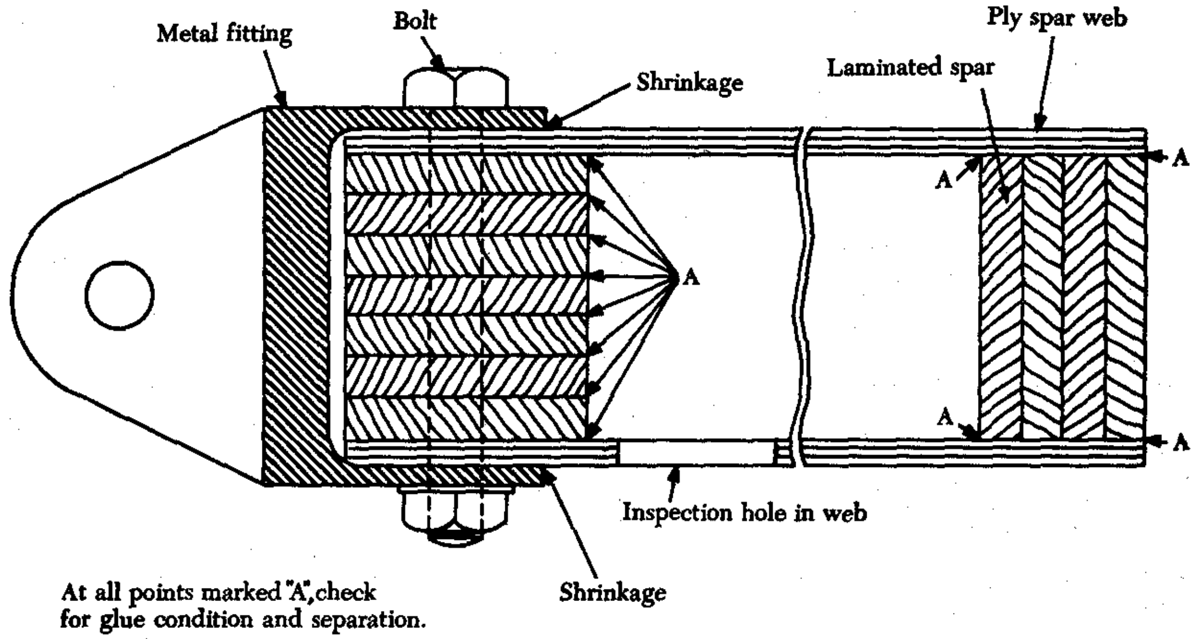


FIGURE 5–106. Laminated joint.

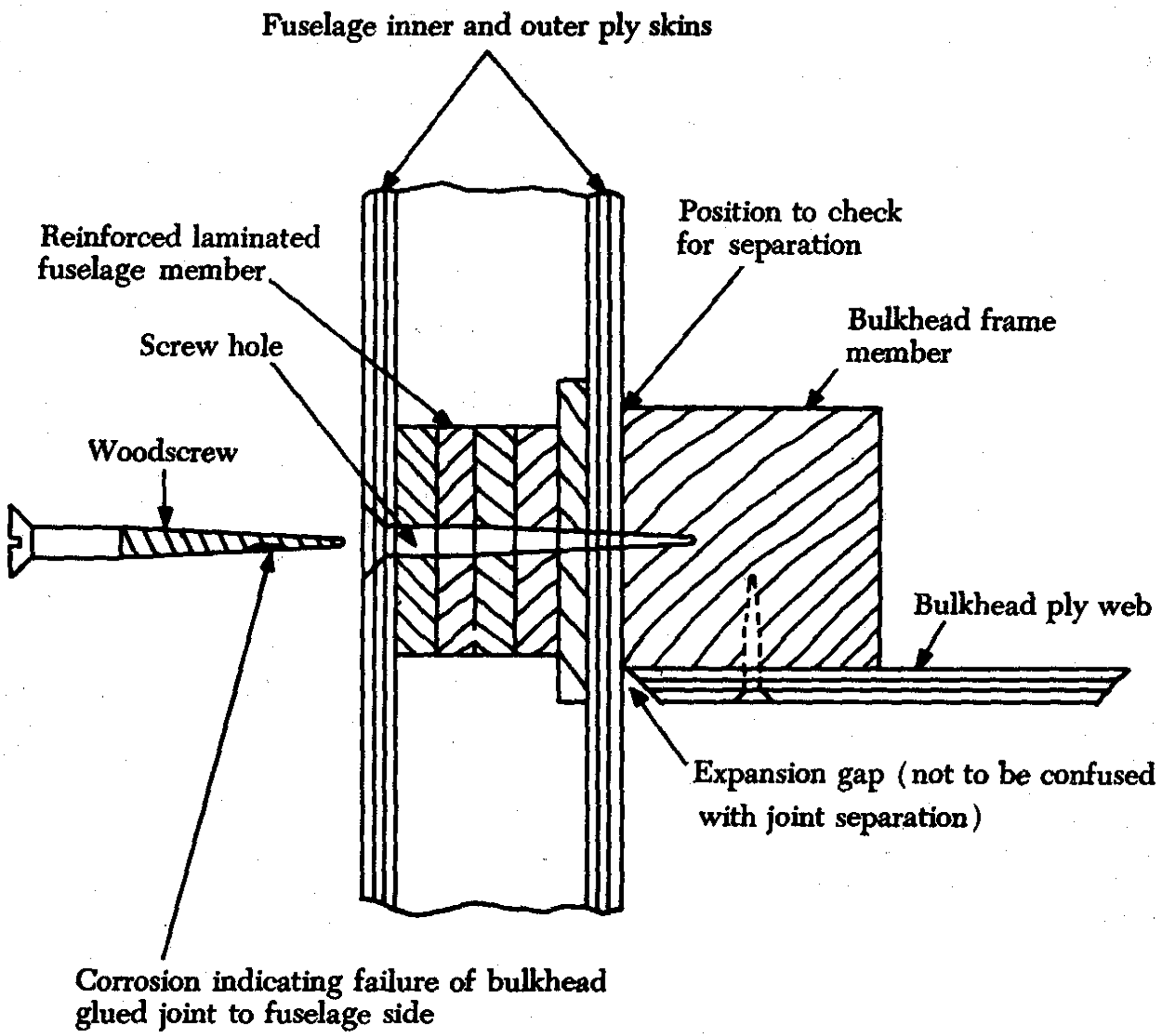


FIGURE 5–107. Checking a wooden structure for water penetration.

part of the structure known to be free from water soakage.

Plain brass screws are normally used for reinforcing glued wooden members, although zinc-coated brass is sometimes used. For hardwoods such as mahogany or ash, steel screws are sometimes used. Unless otherwise specified by the aircraft manufacturer, it is usual to replace screws with new screws of identical length but one gage larger.

Another means of detecting water penetration is to remove the bolts holding the fittings at spar root-end joints, aileron hinge brackets, etc. (figure 5–107). Corrosion on the surface of such bolts and wood discoloration will provide a useful indication of water penetration.

Experience with a particular aircraft will indicate those portions of the structure most prone to water penetration and moisture entrapment, *e.g.*, at windows or the bottom lower structure of entrance doors. However, this is not necessarily indicative of the condition of the complete aircraft.

The condition of the fabric covering on ply surfaces is of great importance. If any doubt exists regarding its protective qualities or if there are any signs of poor adhesion, cracks, or other damage, it should be removed to reveal the ply skin.

The condition of the exposed ply surface should be examined. Water penetration will be shown by dark gray streaks along the grain and a dark discoloration at ply joints or screw holes. If these marks cannot be removed by light scraping or, in the case of advanced deterioration, where there are small surface cracks or separation of the ply laminations, the ply should be replaced. Where evidence of water penetration is found, sufficient areas of the ply surface should be uncovered to determine its extent.

During the inspection, the structure should be examined for other defects of a mechanical nature. Information regarding such defects is presented in the following paragraphs.

Where bolts secure fittings which take load-carrying members, or where the bolts are subject to landing or shear loads, the bolt holes should be examined for elongation or surface crushing of the wood fibers. The bolts should be removed to facilitate the inspection. It is important to ensure that the bolts are a good fit in the holes.

Check for evidence of damage such as bruises or crushing of structural members which can be caused, for example, by overtightening bolts. Repair techniques for such damage are governed by the extent and depth of the defect.

Compression failures, often wrongly referred to as compression "shakes," are caused by rupture across the wood fibers. This is a serious defect which, at times, is difficult to detect. Special care is necessary when inspecting any wooden member which has been subjected to abnormal bending or compression loads during a hard landing. In the case of a member having been subjected to an excessive bending load, the failure will appear on the surface which has been compressed. The surface subjected to tension will normally show no defects. In the case of a member taking an excessive direct compression load, the failure will usually be apparent on all surfaces.

If a compression failure is suspected, a flashlight shone along the member, with the beam of light running parallel to the grain, will assist in revealing this type of failure.

A glued joint may fail in service as a result of an accident or because of excessive mechanical loads having been imposed upon it, either in tension or in shear. It is often difficult to decide the nature of the load which caused the failure, but remember that glued joints are generally designed to take shear loads.

If a glued joint is known to have failed in tension, it is difficult to assess the quality of the joint, since these joints may often show an apparent lack of adhesion. Tension failures often appear to strip the glue from one surface leaving the bare wood. In such cases, the glue should be examined with a magnifying glass, which should reveal a fine layer of wood fibers on the glued surface. The presence of fibers indicates that the joint itself is not at fault. If examination of the glue under magnification does not reveal any wood fibers but shows an imprint of the wood grain, this is caused by pre-drying of the glue before applying pressure during the manufacture of the joints. If the glue exhibits an irregular appearance with star-shaped patterns, this is an indication that pre-curing has occurred before pressure was applied or that pressure has been incorrectly applied or maintained. In all such instances other joints in the aircraft should be suspect.

If a joint is expected to take tension loads, it will be secured by a number of bolts or screws (or both) in the area of tension loading. If a failure occurs in this area, it is usually very difficult to form an opinion of the actual reasons for it, because of considerable breakup of the wood close to the bolts.

In all cases of glued joint failure, whatever the direction of loading, there should be a fine layer of wood fibers adhering to the glue, whether or not the glue has come away completely from one section of the wood member. If there is no evidence of fiber adhesion, this may indicate glue deterioration.

SERVICE AND REPAIR OF WOODEN STRUCTURES

Damage to wooden structures such as wing ribs, spars, and skin frequently requires repair. Whenever major wood parts have been damaged, a detailed inspection must be made. Secondary cracks sometimes start some distance away from the main damage and proceed in unrelated directions.

The purpose of repairing all wooden structural parts is to obtain a structure as strong as the original. Severe damage will require replacement of the entire damaged assembly, but minor damage can be repaired by cutting away the damaged members and replacing them with new sections. This replacement is accomplished by glued, or sometimes glued and nailed, or glued and screw-reinforced splicing.

Materials

Several forms of wood are commonly used in aircraft. Solid wood or the adjective "solid" used with such nouns as beam or spar refers to a member consisting of one piece of wood.

Laminated wood is an assembly of two or more layers of wood which have been glued together with the grain of all layers or laminations approximately parallel. Plywood is an assembled product of wood and glue that is usually made of an odd number of thin plies (veneers) with the grain of each layer at an angle of 90° with the adjacent ply or plies. High-density material includes compreg, impreg, or similar commercial products, heat stabilized wood, or any of the hardwood plywoods commonly used as bearing or reinforcement plates. The woods listed in figure 5–108 are those used for structural purposes. For interior trim, any of the decorative woods such as maple or walnut can be used since strength is of little consideration in this situation.

Species of wood	Strength properties as compared to spruce	Maximum permissible grain deviation (slope of grain)	Remarks
Spruce	100%	1:15	Excellent for all uses. Considered as standard for this table.
Douglas Fir	Exceeds spruce	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Difficult to work with hand tools. Some tendency to split and splinter during fabrication. Large solid pieces should be avoided due to inspection difficulties. Gluing satisfactory.
Noble Fir	Slightly exceeds spruce except 8 percent deficient in shear.	1:15	Satisfactory characteristics with respect to workability, warping, and splitting. May be used as direct substitute for spruce in same sizes providing shear does not become critical. Hardness somewhat less than spruce. Gluing satisfactory.
Western Hemlock	Slightly exceeds spruce.	1:15	Less uniform in texture than spruce. May be used as direct substitute for spruce. Gluing satisfactory.
Pine, Northern White	Properties between 85 percent and 96 percent those of spruce.	1:15	Excellent working qualities and uniform in properties but somewhat low in hardness and shock-resisting capacity. Cannot be used as substitute for spruce without increase in sizes to compensate for lesser strength. Gluing satisfactory.
White Cedar, Port Orford	Exceeds spruce	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Easy to work with hand tools. Gluing difficult but satisfactory joints can be obtained if suitable precautions are taken.
Poplar, Yellow	Slightly less than spruce except in compression (crushing) and shear.	1:15	Excellent working qualities. Should not be used as a direct substitute for spruce without carefully accounting for slightly reduced strength properties. Somewhat low in shock-resisting capacity. Gluing satisfactory.

FIGURE 5–108. Woods for aircraft use.

All wood and plywood used in the repair of aircraft structures must be of aircraft quality. The species used to repair a part should be the same as that of the original whenever possible. If it is necessary to substitute a different species, follow the recommendations of the aircraft manufacturer in selecting a different species.

Defects Permitted.

a. Cross grain. Spiral grain, diagonal grain, or a combination of the two is acceptable providing the grain does not diverge from the longitudinal axis of the material more than specified in column 3 of figure 108. A check of all four faces of the board is necessary to determine the amount of divergence. The direction of free-flowing ink will frequently assist in determining grain direction.

b. Wavy, curly, and interlocked grain. Acceptable, if local irregularities do not exceed limitations specified for spiral and diagonal grain.

c. Hard knots. Sound hard knots up to 3/8-inch in maximum diameter are acceptable providing: (1) they are not in projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of flanges of box beams (except in lowly stressed portions); (2) they do not cause grain divergence at the edges of the board or in the flanges of a beam more than specified in column 3; and (3) they are in the center third of the beam and are not closer than 20 inches to another knot or other defect (pertains to 3/8-inch knots—smaller knots may be proportionately closer). Knots greater than 1/4-inch must be used with caution.

d. Pin knot clusters. Small clusters are acceptable providing they produce only a small effect on grain direction.

e. Pitch pockets. Acceptable, in center portion of a beam providing they are at least 14 inches apart when they lie in the same growth ring and do not exceed 1 1/2 inch length by 1/8-inch width by 1/8-inch depth and providing they are not along the projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of the flanges of box beams.

f. Mineral streaks. Acceptable, providing careful inspection fails to reveal any decay.

Defects Not Permitted.

g. Cross grain. Not acceptable, unless within limitations noted in **a.** above.

h. Wavy, curly, and interlocked grain. Not acceptable, unless within limitations noted in **b.** above.

i. Hard knots. Not acceptable, unless within limitations noted in **c.** above.

j. Pin knot clusters. Not acceptable, if they produce large effect on grain direction.

k. Spike knots. These are knots running completely through the depth of a beam perpendicular to the annual rings and appear most frequently in quartersawed lumber. Reject wood containing this defect.

l. Pitch pockets. Not acceptable, unless within limitations noted in **e.** above.

m. Mineral streaks. Not acceptable, if accompanied by decay (see **f.**).

n. Checks, shakes, and splits. Checks are longitudinal cracks extending, in general, across the annual rings. Shakes are longitudinal cracks usually between two annual rings. Splits are longitudinal cracks induced by artificially induced stress. Reject wood containing these defects.

o. Compression wood. This defect is very detrimental to strength and is difficult to recognize readily. It is characterized by high specific gravity; has the appearance of an excessive growth of summer wood; and in most species shows but little contrast in color between spring wood and summer wood. In doubtful cases reject the material, or subject samples to a toughness machine test to establish the quality of the wood. Reject all material containing compression wood.

p. Compression failures. This defect is caused from the wood being overstressed in compression due to natural forces during the growth of the tree, felling trees on rough or irregular ground, or rough handling of logs or lumber. Compression failures are characterized by a buckling of the fibers that appear as streaks on the surface of the piece substantially at right angles to the grain, and vary from pronounced failures to very fine hairlines that require close inspection to detect. Reject wood containing obvious failures. In doubtful cases reject the wood, or make a further inspection in the form of microscopic examination or toughness test, the latter means being the more reliable.

q. Decay. Examine all stains and discolorations carefully to determine whether or not they are harmless, or in a stage of preliminary or advanced decay. All pieces must be free from all forms of decay.

GLUES

Glues used in aircraft repair fall into two general groups: (1) Casein and (2) resin glues. Any glue that meets the performance requirements of applicable U.S. Military Specifications or has previously been accepted by the FAA is satisfactory for use in certificated civil aircraft. In all cases, glues are to be used strictly in accordance with the glue manufacturer's recommendations.

Casein glues have been widely used in wood aircraft repair work. The forms, characteristics, and properties of water-resistant casein glues have remained substantially the same for many years,

except for the addition of preservatives. Casein glues for use in aircraft should contain suitable preservatives, such as the chlorinated phenols and their sodium salts, to increase their resistance to organic deterioration under high-humidity exposures. Most casein glues are sold in powder form ready to be mixed with water at ordinary room temperatures.

Synthetic resin glues for wood are outstanding in that they retain their strength and durability under moist conditions and after exposure to water. The best known and most commonly used synthetic resin glues are the phenol-formaldehyde, resorcinol-formaldehyde, and urea-formaldehyde types. The resorcinol-formaldehyde type glue is recommended for wood aircraft applications. Materials, such as walnut shell flour, are often added by the glue manufacturer to the resin glues to give better working characteristics and joint-forming properties. The suitable curing temperatures for both urea-formaldehyde and resorcinol glues are from 70° F. up. At the 70° F. minimum temperature, it may take as long as 1 week for the glue line in a spar splice to cure to full strength. Thinner pieces of wood and/or higher curing temperatures shorten curing time considerably. The strength of a joint cannot be depended upon if assembled and cured at temperatures below 70° F.

For those not familiar with the terms used relating to synthetic resin adhesives and their application, a glossary follows.

(1) **Cold setting adhesive.** An adhesive which sets and hardens satisfactorily at ordinary room temperature, *i.e.*, 50° F. to 86° F. (10° C. to 32° C.) within a reasonable period.

(2) **Close contact adhesive.** A nongap-filling adhesive suitable for use only in those joints where the surfaces to be joined can be brought into close contact by means of adequate pressure, and where glue lines exceeding 0.005 in. can be avoided with certainty.

(3) **Closed assembly time.** The time elapsing between the assembly of the joints and the application of pressure.

(4) **Double spread.** The spread of adhesive equally divided between the two surfaces to be joined.

(5) **Gap-filling adhesive.** An adhesive suitable for use in those joints where the surfaces to be joined may or may not be in close or continuous contact, owing either to the impossibility of applying adequate pressure or to slight inaccuracies of machining. Unless otherwise stated by the manufacturer, gap-filling adhesives are not suitable for use where the glue line exceeds 0.050 in. in thickness.

(6) **Glue line.** The resultant layer of adhesive joining any two adjacent wood layers in the assembly.

(7) **Hardener.** A material used to promote the setting of the glue. It may be supplied separately in either liquid or powder form, or it may have been incorporated with the resin by the manufacturer. It is an essential part of the adhesive, the properties of which depend upon using the resin and hardener as directed.

(8) **Open assembly time.** The period of time between the application of the adhesive and the assembly of the joint components.

(9) **Single spread.** The spread of adhesive to one surface only.

(10) **Spread of adhesive.** The amount of adhesive applied to join two surfaces.

(11) **Synthetic resin.** A synthetic resin (phenolic) is derived from the reaction of a phenol with an aldehyde. A synthetic resin (amino plastic) is derived from the reaction of urea, thiourea, melamine, or allied compounds with formaldehyde.

(12) **Synthetic resin adhesive.** A composition substantially consisting of a synthetic resin, either the phenolic or amino type, but including any hardening agent or modifier which may have been added by the manufacturer or which must be added before use, according to manufacturer's instructions.

Synthetic resin adhesives are used extensively for joining wooden structures to avoid the localized stresses and strains which may be set up by the use of mechanical methods of attachment. The strength of such structures depends largely on the efficiency of the glued joints, and cannot be verified by means other than the destruction of the joints. Acceptance must be governed by adequate precautions throughout the gluing process and by the results obtained by representative test pieces.

Synthetic resin adhesives usually consist of two separate parts, the resin and the hardener. The resin develops its adhesive properties only as a result of a chemical reaction between it and the hardener. With some adhesives, an inert filler is added to increase viscosity and to improve the gap-filling properties of the mixed adhesive.

Synthetic resins can be obtained either in liquid or powder form. In general, powder resins have the longest storage life, since they are less susceptible to deterioration from high ambient temperatures.

Powder resins must be mixed with water in accordance with the manufacturer's instructions before they can be used in conjunction with a hardener. To obtain satisfactory results, it is essential that they be properly mixed. Once mixed, the adhesive must not be diluted unless this is permitted by the manufacturer's instructions. In many instances, manufacturers specify a definite period of time which must elapse between the mixing and the application of the adhesive. During this period, the adhesive should be covered to prevent contamination. When resins are supplied in liquid form, they are ready for immediate use in conjunction with the hardener. Liquid resin must not be diluted unless this is permitted by the manufacturer's instructions.

When mixing the hardener with the resin, the proportions must be in accordance with the manufacturer's instructions. Hardeners should not be permitted to come into contact with the resin except when the adhesive is mixed prior to use.

GLUING

The surface to be joined must be clean, dry, and free from grease, oil, wax, paint, etc. It is important that the parts to be joined have approximately the same moisture content, since variations will cause stresses to be set up because of swelling or shrinkage which may lead to the failure of the joint.

The moisture content of wood can be determined by taking a sample of the wood to be glued, weighing it, and then drying it in an oven at a temperature of 100° C. to 105° C. Calculate the moisture content by using the formula:

$$\frac{W_1 - W_2}{W_2} \times 100$$

where,

W_1 = the weight of the sample prior to drying.

W_2 = the weight of the sample after drying.

Example

Substitution and solution of above formula:

$$\frac{2 - 1.5}{1.5} \times 100 = .33 \text{ or } 33\%.$$

The approximate moisture content can also be determined by using a moisture meter. When this instrument is used, its accuracy should be checked periodically.

The wood to be glued should be at room temperature. The surfaces to be joined should not be overheated since this affects the surface of the wood and reduces the efficiency of most synthetic resin adhesives.

Synthetic resin adhesives are very sensitive to variations in temperature. The usable (pot) life of the adhesive, proportion of hardener to use, and clamping time all depend largely on the temperature of the glue room at the time of gluing.

It is generally desirable to apply adhesive to both surfaces of the material. This applies particularly where the glue line is likely to be variable or when it is not possible to apply uniform pressure.

The adhesive can be applied by a brush, glue spreaders, or rubber rollers that are slightly grooved. The amount of adhesive required depends largely on the type of wood and the accuracy of machining. Dense wood requires less adhesive than soft or porous types. Adhesive should be applied generously to an end grain. Smooth, side-grained surfaces may be satisfactorily glued with a thin spread. The general rule is that the adhesive should completely cover the surfaces to be glued and remain tacky until pressure is applied to the joint.

Difficult gluing conditions may occur when a soft wood is to be glued to one much denser because the adhesive tends to flow into the more porous wood. In such instances, unless otherwise specified by the manufacturer of the adhesive, precoating and partial drying of the softer surface, before normal spreading, is suggested.

Care should be taken before applying the adhesive to ensure that the surfaces will make good contact and that the joint will be positioned correctly. The interval between the application of the adhesive and assembly of the joint should be kept as short as possible. Some adhesives contain solvents which should be allowed to evaporate before the joint is assembled. If this is not done, bubbles may be created and result in a weak joint. For adhesives of this type, the manufacturer will specify a time interval which should elapse before the joint is closed.

To ensure that the two surfaces bind properly, pressure must be applied to the joint. The strength of the joint will depend to a great extent upon how evenly the force is applied. The results of evenly and unevenly applied pressure are illustrated in figure 5–109.

Pressure is used to squeeze the glue out into a thin continuous film between the wood layers, to force air from the joint, to bring the wood surfaces into intimate contact with the glue, and to hold them in this position during the setting of the glue.

Pressure should be applied to the joint before the glue becomes too thick to flow and is accomplished by means of clamps, presses, or other mechanical devices.

Non-uniform gluing pressure commonly results in weak and strong areas in the same joint. The amount of pressure required to produce strong joints in aircraft assembly operations may vary from 125 to 150 p.s.i. for softwoods and 150 to 200 p.s.i. for hardwoods. Insufficient pressure to poorly machined wood surfaces usually results in thick glue lines, which indicates a weak joint, and should be carefully guarded against.

The methods used in applying pressure to joints in aircraft gluing operations range from the use of brads, nails, screws, or clamps to the use of hydraulic and electrical power presses. Hand-nailing is used rather extensively in the gluing of ribs and in the application of plywood skins to the wing, control surfaces, and fuselage frames.

On small joints, such as those found in wood ribs, the pressure is usually applied only by nailing the joint gussets in place after spreading the glue. Since small nails must be used to avoid splitting, the gussets should be comparatively large in area to compensate for the relative lack of pressure. At least four nails (cement-coated or galvanized and barbed) per sq. in. are to be used, and in no event must nails be more than ¾ in. apart. Small brass screws may also be used advantageoulsy when the particular parts to be glued are relatively small and do not allow application of pressure by means of clamps.

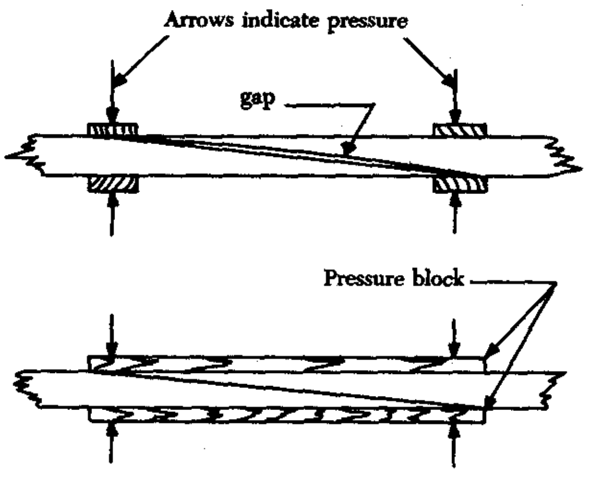


FIGURE 5–109. Results of uneven and even pressure.

Apply pressure using cabinet maker clamps, parallel clamps, or similar types. Use handspring clamps in conjunction with softwood only. Because of their limited pressure area, they should be applied with a pressure-distributing strip or block at least twice as thick as the member to be pressed.

High clamping pressures are neither essential nor desirable, provided good contact between the surfaces being joined is obtained. When pressure is applied, a small quantity of glue should be squeezed from the joint. This should be wiped off before it dries. The pressure must be maintained during the full setting time. This is important since the adhesive will not reunite if disturbed before it is fully set.

The setting time depends on the temperature at which the operation is carried out. An increase in temperature results in a decrease in the setting period. Conversely, a decrease in temperature causes an increase in the setting time.

Full joint strength and resistance to moisture will develop only after conditioning for at least 2 days. Again, this depends on the ambient temperature and the type of hardener used. Usually when repairs are made, the joint will be of sufficient strength after 1 day.

Testing Glued Joints

Frequent tests should be made to ensure that the joints are satisfactory. Whenever possible, tests should be carried out on pieces cut from the actual component. The test samples should be 1 in. wide and at least 2 in. long. The pieces should be joined with one member overlapping the other by ⅜ in. The glued test sample should be placed in a vice and the joint broken by exerting pressure on the overlapping member. The fractured glue faces should show at least 75% of the wood fibers evenly distributed over the fractured glue surfaces. A typical broken test piece is shown in figure 5–110.

Where repairs are to be made on old aircraft in which the wooden structure is joined with a casein cement, all traces of the casein cement must be removed from the joint, since this material is alkaline and is liable to affect the setting of a synthetic resin adhesive. Local staining of the wood by the casein cement can, however, be disregarded.

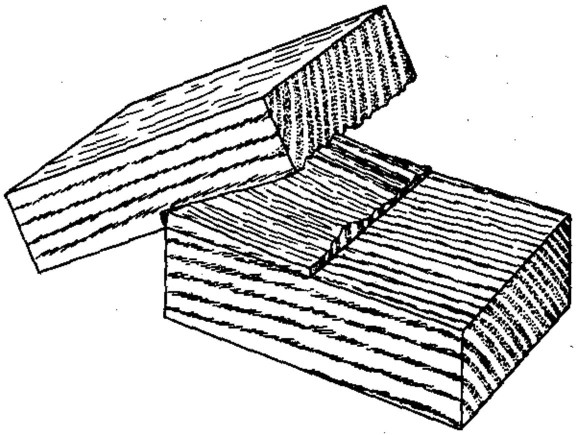


FIGURE 5–110. Typical broken test piece.

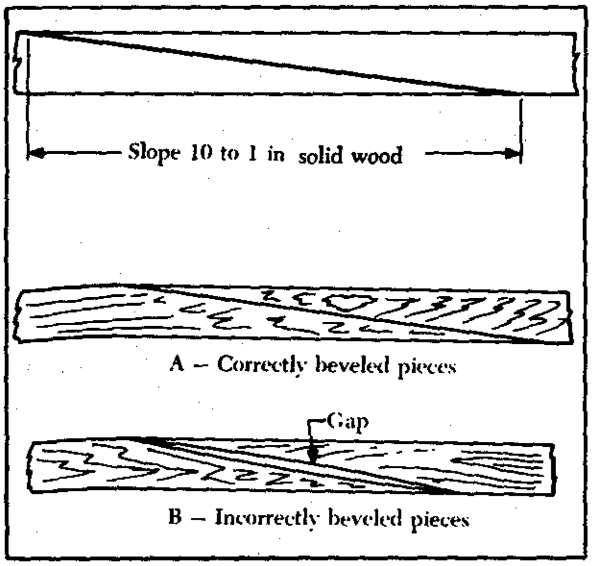


FIGURE 5–111. Beveling scarf joint.

SPLICED JOINTS

The scarf joint is generally used in splicing structural members in aircraft. As illustrated in figure 5–111, the two pieces to be joined are beveled and glued. The slope of the bevel should be not less than 10 to 1 in solid wood and 12 to 1 in plywood. Make the scarf cut in the general direction of the grain slope as shown in figure 5–111.

The chief difficulty encountered in making this type of joint is that of obtaining the same bevel on each piece. The strength of the joint will depend upon the accuracy of the two beveled surfaces, because an inaccurate bevel will reduce the amount of effective glue area. (See figure 5–111.)

One method of producing an accurate scarf joint is illustrated in figure 5–112. After the two bevels are cut, the pieces are clamped to a 2X4 backboard or some similar material. A fine-tooth saw is then run all the way through the joint. One of the pieces is then tapped on the end until it will move no farther, and the saw is again passed through the joint. This procedure is continued until the joint is perfect. A light cut of a plane is then used to smooth the surfaces of the joint.

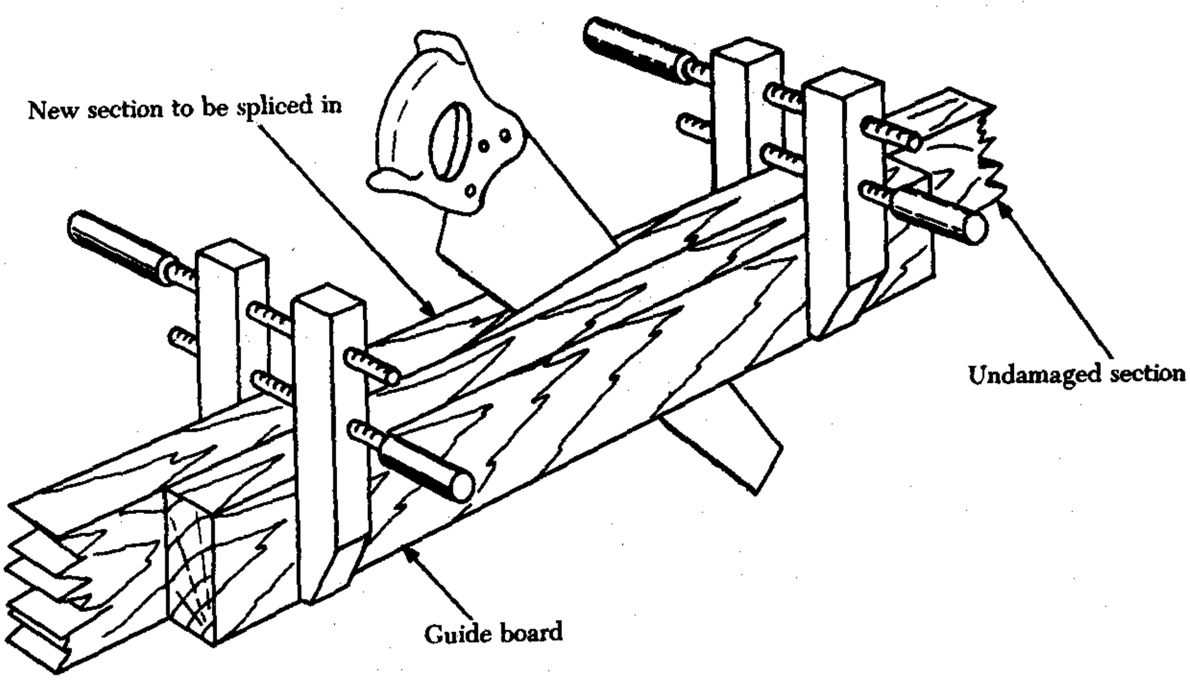


FIGURE 5–112. Making a scarf joint.

It is recommended that no more than 8 hrs. be permitted to elapse between final surfacing and gluing. The gluing surfaces should be machined smooth and true with planers, jointers, or special miter saws. Planer marks, chipped or loosened grain, and other surface irregularities are not permitted. Sandpaper must never be used to smooth softwood surfaces that are to be glued. Sawed surfaces must be similar to well-planed surfaces in uniformity, smoothness, and freedom from crushed fibers.

Tooth-planing, or other means of roughening smooth, well-planed surfaces of normal wood before gluing are not recommended. Such treatment of well-planed wood surfaces may result in local irregularities and objectionable rounding of edges. Although sanding of planed surfaces is not recommended for softwoods, sanding is a valuable aid in improving the gluing characteristics of some hard plywood surfaces, wood that has been compressed through exposure to high pressure and temperatures, resin-impregnated wood (impreg and compreg), or laminated paper plastic (papreg).

PLYWOOD SKIN REPAIRS

Most skin repairs can be made using either the surface or overlay patch, the splayed patch, the plug patch, or the scarf patch. Probably the easiest to make is the surface patch. Surface patches should not be used on skins over ⅛-in. thick.

To repair a hole by this method, trim the damaged skin to a rectangular or triangular shape depending upon the exact location of the damage relative to the framing members (figure 5–113). Where

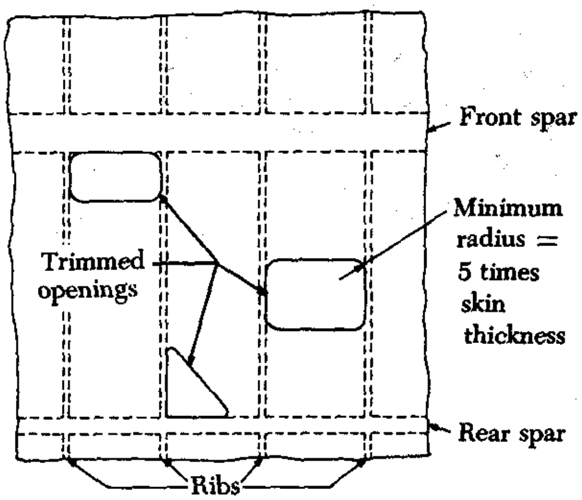


FIGURE 5–113. Typical shapes for damage removal.

the framing members form a square corner and the damage does not extend to the next parallel member, a triangular opening should be made. The corners of the cutouts should be rounded with a radius of at least five times the thickness of the skin.

Doublers, made of plywood at least as thick as the skin, are reinforcements placed under the edge of the hole inside the skin. The doublers are nailed and gluded in place. The doublers are extended from one framing member to another and are strengthened at the ends by saddle gussets attached to the framing members.

A patch large enough to extend at least 12 times the skin thickness beyond all edges of the opening is cut from material of the same kind and thickness as the original panel. The edges of the patch are then beveled (scarfed), as shown in figure 5–114.

It is usually impossible to use clamps when gluing an external patch; therefore, the pressure is applied by some other means. It is usually done by placing heavy weights on the patch until it is dry. Two or three small nails driven through the patch will prevent slipping during the drying.

After a surface patch has dryed, it should be covered with fabric. The fabric should overlap the original plywood skin by at least 2 in.

Surface patches located entirely aft of the 10% chord line, or which wrap around the leading edge and terminate aft of the 10% chord line are permissible. The leading edge of a surface patch should be beleved with an angle of at least four times the skin thickness. Surface patches can have as much as a 50–in. perimeter and can extend from one rib to the next. The face-grain direction of the patch must be in the same direction as the original skin. Surface patches should not be used on skins over ⅛-in. thick.

Flush Patches

In places where an external patch would be objectionable, such as on wing coverings or fuselage skin, etc., a flush patch can be used.

Plug Patches

Two types of plug patches, oval and round, can be used on plywood skins. Since the plug patch is strictly a skin repair, it should be used only for damage that does not involve the supporting structure under the skin.

A plug patch has edges cut at right angles to the surface of the skin. The skin is cut out to a clean round or oval hole with square edges. The patch is cut to the exact size of the hole, and when installed,

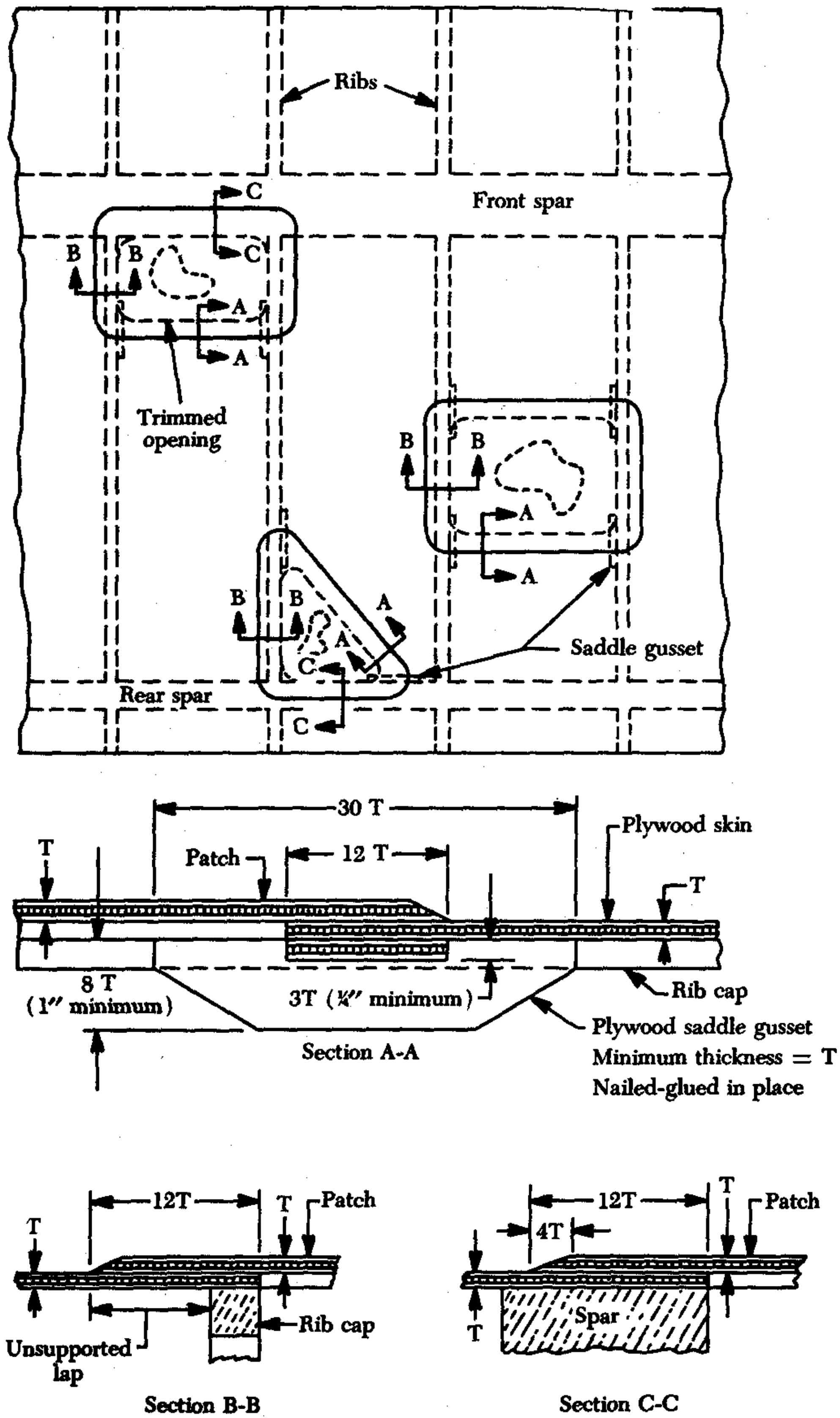
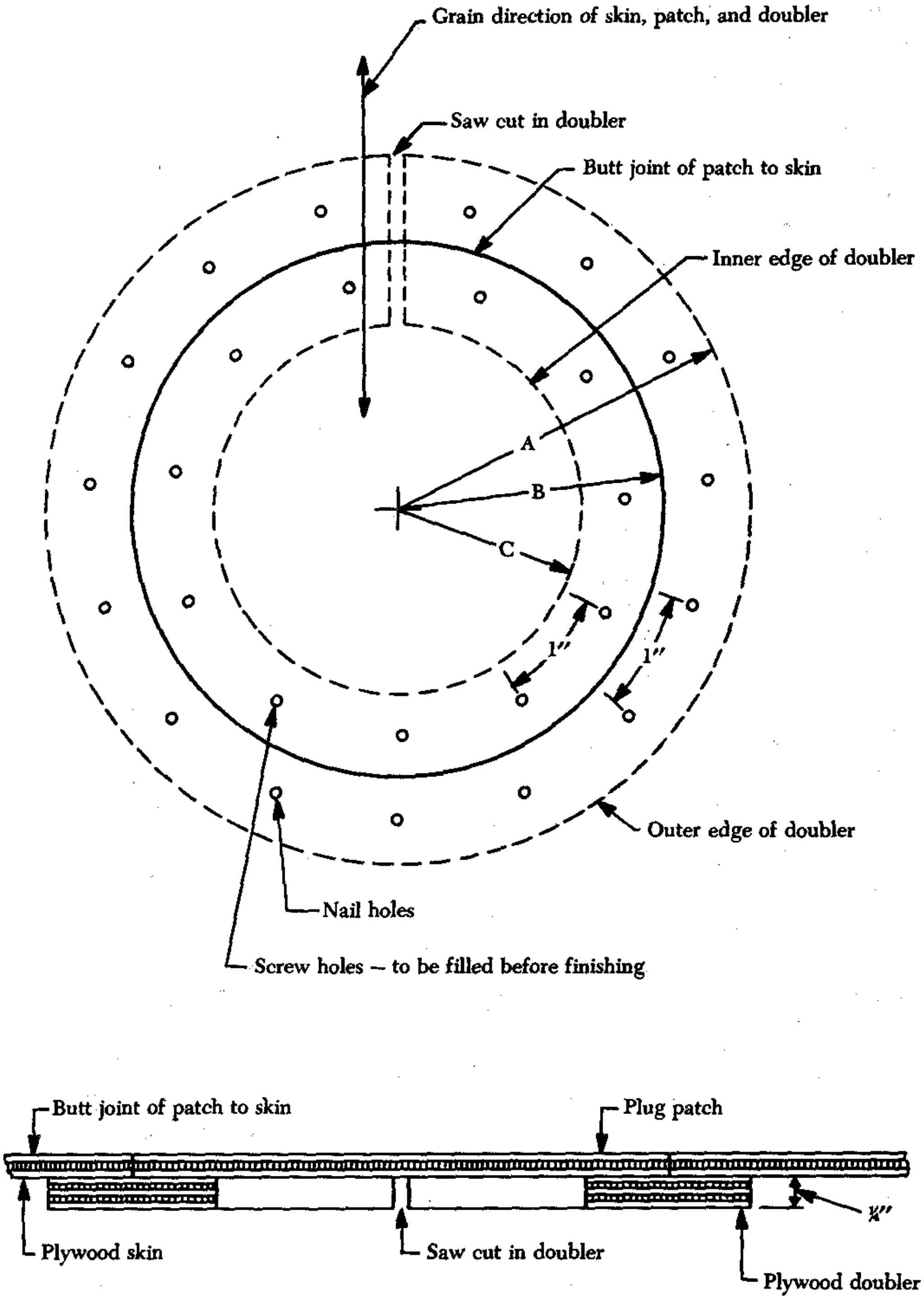


FIGURE 5–114. Surface patches.



Dimensions

	A	B	C
Small circular plug patch	2⅝	2	1⅜
Large circular plug patch	3⅝	3	2⅜

(Two rows of screws and nails required for large patch)

FIGURE 5-115. A round plug patch.

the edge of the patch forms a butt joint with the edge of the hole.

A round plug patch, shown in figure 5–115, can be used where the cutout hole is no larger than 6 in. in diameter. Large and small circular patches have been designed for holes of 6 and 4 in. in diameter.

The steps for making a circular or round plug patch are:

(1) Cut a patch of the correct dimension for the repair. The patch must be of the same material and thickness as the original skin. Orientation of the face-grain direction of the round plug patch to that of the skin surface is no problem, since the round patch may be rotated until grain directions match.

(2) Lay the patch over the damaged spot and mark a circle of the same size as the patch.

(3) Cut the skin out so that the patch fits snugly into the hole around the entire perimeter.

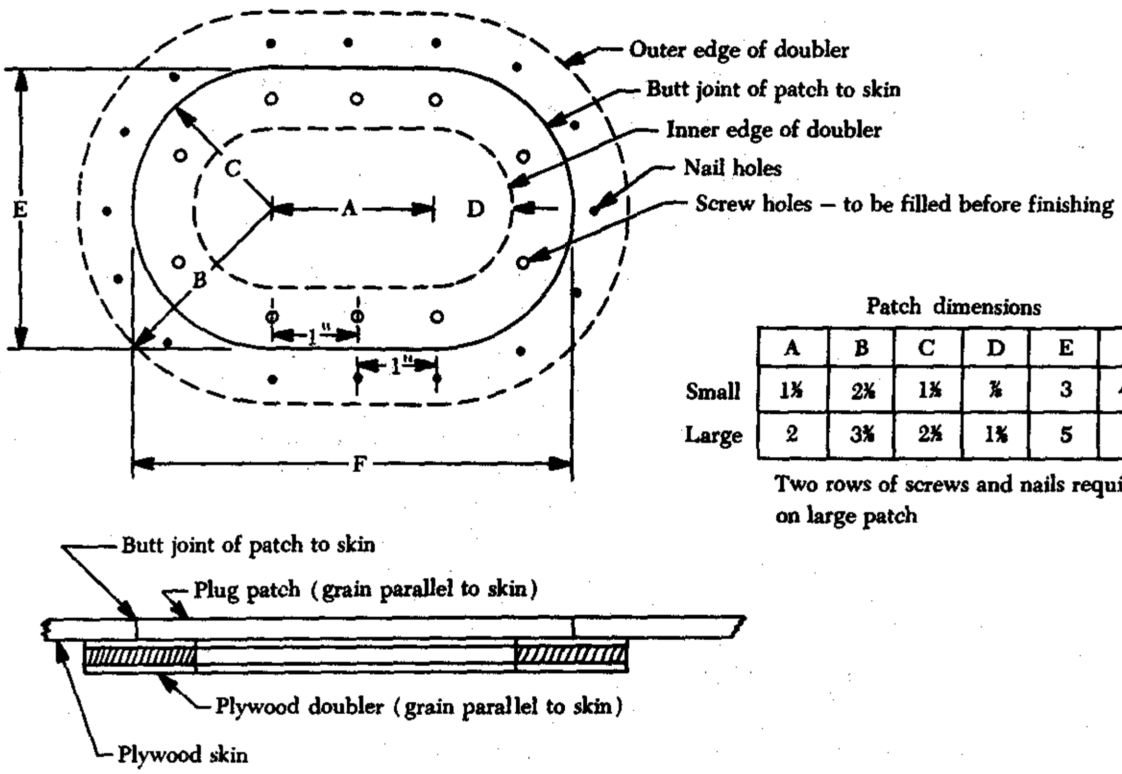
(4) Cut a doubler of ¼-in. plywood so that its outside radius is ⅝ in. greater than the hole to be patched and the inside radius is ⅝ in. less. For a large patch, these dimensions would be ⅞ in. each. The doubler should be of a soft plywood such as poplar.

(5) Cut the doubler through one side so that it can be inserted through to the back of the skin. Apply a coat of glue to the outer half of the doubler surface where it will bear against the inner surface of the skin.

(6) Install the doubler by slipping it through the cutout hole and centering it so that it is concentric with the hole. Nail it in place with nailing strips, using a bucking bar or similar object for backing. Waxed paper must be placed between the nailing strips and the skin.

(7) After the glue has set in the installation of the doubler, apply glue to the surface of the doubler where the patch is to join and to the same area on the patch. Insert the patch in the hole.

(8) Apply pressure to the patch by means of a pressure plate and No. 4 wood screws placed at approximately 1-in. spacing. Waxed paper or cellophane placed be-



Patch dimensions

	A	B	C	D	E	F
Small	1⅜	2⅜	1⅜	⅞	3	4½
Large	2	3⅜	2⅜	1⅜	5	7

Two rows of screws and nails required on large patch

FIGURE 5–116. An oval patch.

tween the plate and patch will prevent glue from sealing the plate to the patch.

(9) After the glue has set, remove the nails and screws. Fill the nail and screw holes, sand, and finish to match the original surface.

The steps for making an oval plug patch, figure 5–116, are identical with those for making the round patch. The maximum dimensions for large oval patches are 7-in. long and 5-in. wide. Oval patches must be prepared with the face grain carefully oriented to the same direction as the original skin.

Splayed Patch

A splayed patch is a patch fitted into the plywood to provide a flush surface. The term "splayed" denotes that the edges of the patch are tapered, but the slope is steeper than is allowed in scarfing operations. The slope of the edges is cut at an angle of five times the thickness of the skin.

Splayed patches may be used where the largest dimension of the hole to be repaired is not more than 15 times the skin thickness and the skin thickness is not more than 1/10 in.

Lay out the patch as shown in figure 5–117. Tack a small piece of plywood over the hole for a center point. Draw two concentric circles around the damaged area. The difference between the radii of the circles is five times the skin thickness. The inner circle marks the limit of the hole and the outer one marks the limit of the taper.

Cut out the inner circle and taper the hole evenly to the outer mark with a chisel, knife, or rasp.

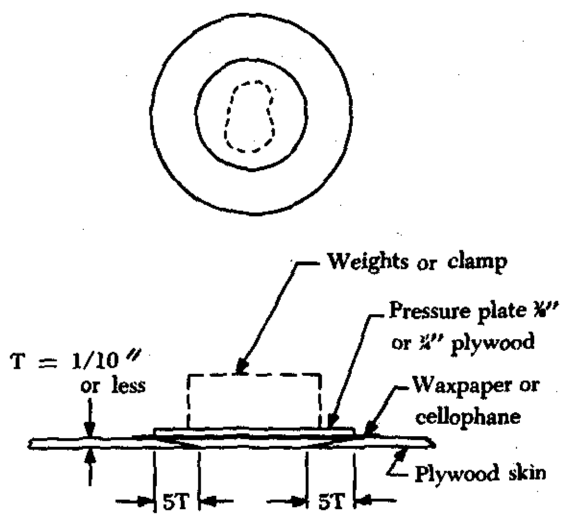


FIGURE 5–117. A splayed patch.

Prepare a circular patch, cut and tapered to match the hole. The patch is of the same type and thickness as the plywood being repaired.

Apply glue to the beveled surfaces and place the patch into place with the face-grain direction matching that of the original surface.

After the patch is in place, a pressure plate cut to the exact size of the patch is centered over the patch, with waxed paper between the two, and pressed firmly against the patch with a weight (sometimes a sandbag) or clamp. Since there is no reinforcement behind the splayed patch, use care to prevent excess pressure. After the glue has set, fill, sand, and finish the patch to match the original surface.

Scarf Patch

A properly prepared and inserted scarf patch is the best repair for damaged plywood and is preferred for most skin repairs. The scarf patch differs from the splayed patch in that the edges are scarfed to a 12 to 1 slope instead of the 5 to 1 used with the splayed patch. The scarf patch also uses reinforcements under the patch where the glue joints occur.

Much of the outside surface of plywood aircraft is curved. If the damaged plywood skin has a radius of curvature greater than 100 times the skin thickness, a scarf patch can be installed. Backing blocks or other reinforcements must be shaped to fit the skin curvature.

Figures 5–118 and 5–119 illustrate methods for making scarfed flush patches. Scarf cuts in plywood are made by hand plane, spoke shave, scraper, or accurate sandpaper block. Rasped surfaces, except at the corners of scarf patches and sawed surfaces, should be avoided since they are likely to be rough or inaccurate.

When the back of a damaged plywood skin is accessible (such as a fuselage skin), it should be repaired with scarf patches following the details shown in figure 5–118. Whenever possible, the edge of the patch should be supported as shown in section C–C. When the damage follows or extends to a framing member, the scarf should be supported as shown in section B–B.

Damages that do not exceed 25 times the skin thickness in diameter after being trimmed to a circular shape can be repaired as shown in figure 5–118, section D–D, provided the trimmed opening is not nearer than 15 times the skin thickness to a framing member. The backing block is carefully

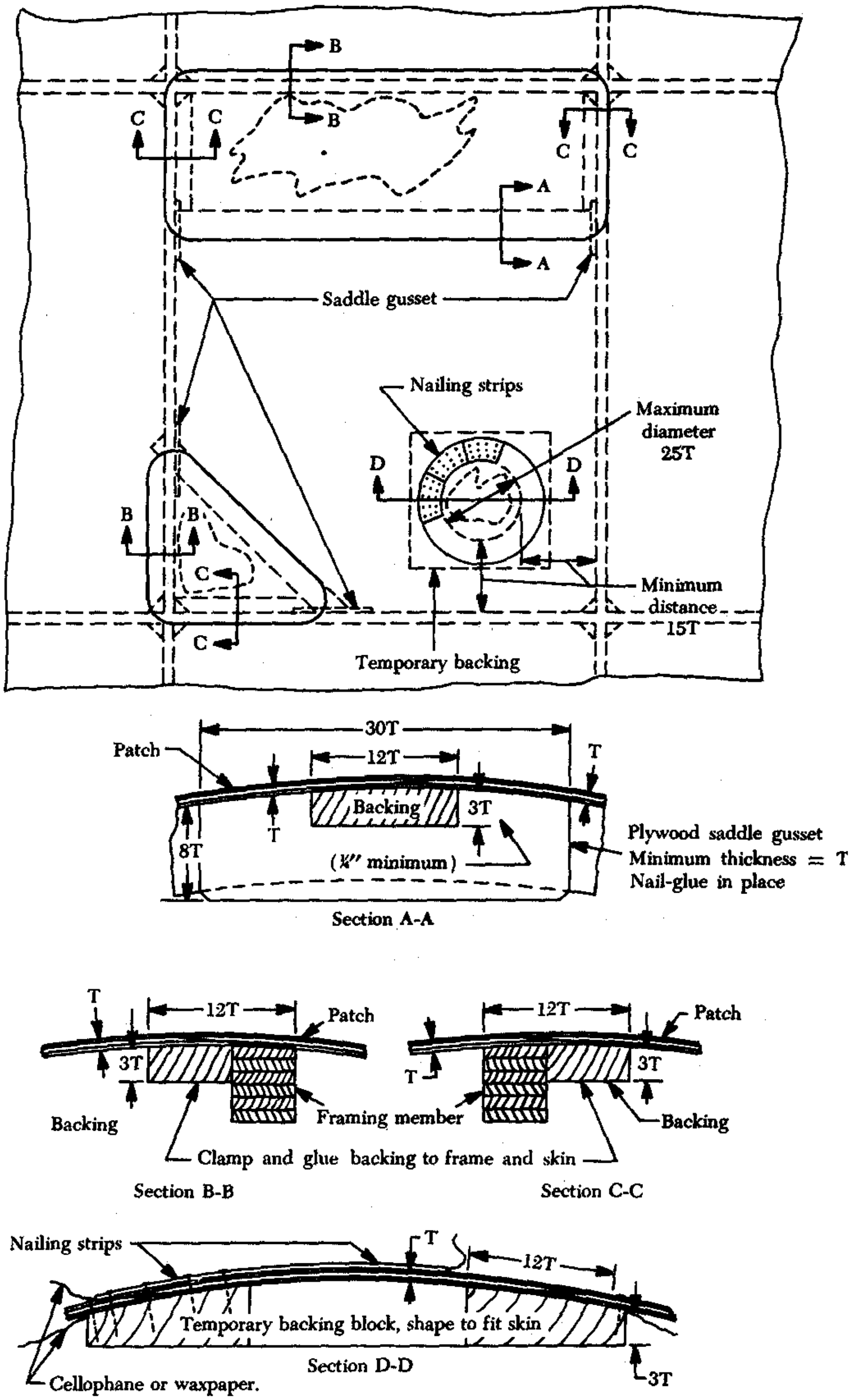


FIGURE 5–118. Scarf patches, back of skin accessible.

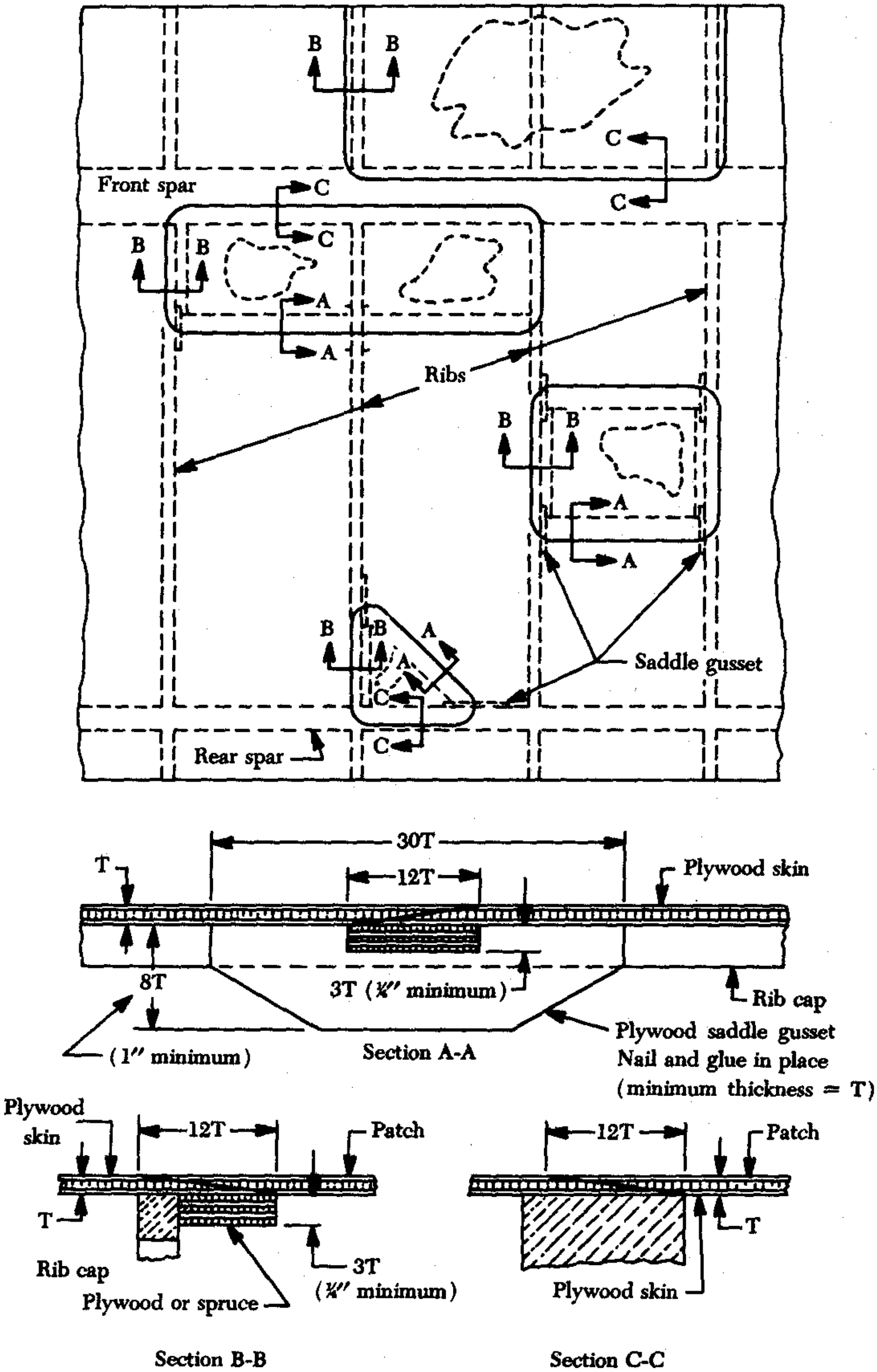


FIGURE 5–119. Scarf patches, back of skin not accessible.

shaped from solid wood and fitted to the inside surface of the skin, and it is temporarily held in place with nails. A hole, the exact size of the inside circle of the scarf patch, is made in the block and is centered over the trimmed area of damage. The block is removed after the glue on the patch has set, leaving a flush surface to the repaired skin.

When the back of a damaged plywood skin is not accessible, it should be repaired as outlined in figure 5-119. After removing damaged sections, install backing strips along all edges that are not fully backed by a rib or a spar. To prevent warping of the skin, backing strips should be made of a soft-textured plywood, such as yellow poplar or spruce rather than solid wood. All junctions between backing strips and ribs or spars should have the end of the backing strip supported by a saddle gusset of plywood.

If needed, nail and glue the new gusset plate to the rib. It may be necessary to remove and replace the old gusset plate with a new saddle gusset, or it may be necessary to nail a saddle gusset over the original.

Attach nailing strips to hold backing strips in place while the glue sets. Use a bucking bar where necessary to provide support for nailing. Unlike the smaller patches made in a continuous process, work on the aircraft must wait while the glue, holding the backing strips, sets. After the glue sets, fill and finish to match the original skin.

Fabric Patch

Small holes that do not exceed 1 in. in diameter, after being trimmed to a smooth outline, can be repaired by doping a fabric patch on the outside of the plywood skin. The edges of the trimmed hole should first be sealed, and the fabric patch should overlap the plywood skin by at least 1 in. Holes nearer than 1 in. to any frame member, or in the wing leading edge or frontal area of the fuselage, should not be repaired with fabric patches.

SPAR AND RIB REPAIR

The web members of a spar or rib can be repaired by applying an external or flush patch, provided the damaged area is small. Plates of spruce or plywood of sufficient thickness to develop the longitudinal shear strength can be glued to both sides of the spar. Extend the plates well beyond the termination of the crack as shown in figure 5-120.

If more extensive damage has occurred, the web should be cut back to structural members and repaired with a scarf patch. Not more than two splices should be made in any one spar.

A spar may be spliced at any point except under wing attachment fittings, landing-gear fittings, engine-mount fittings, or lift-and-interplane strut fittings. Do not permit these fittings to overlap any part of the splice. Splicing under minor fittings such as drag wire, antidrag wire, or compression

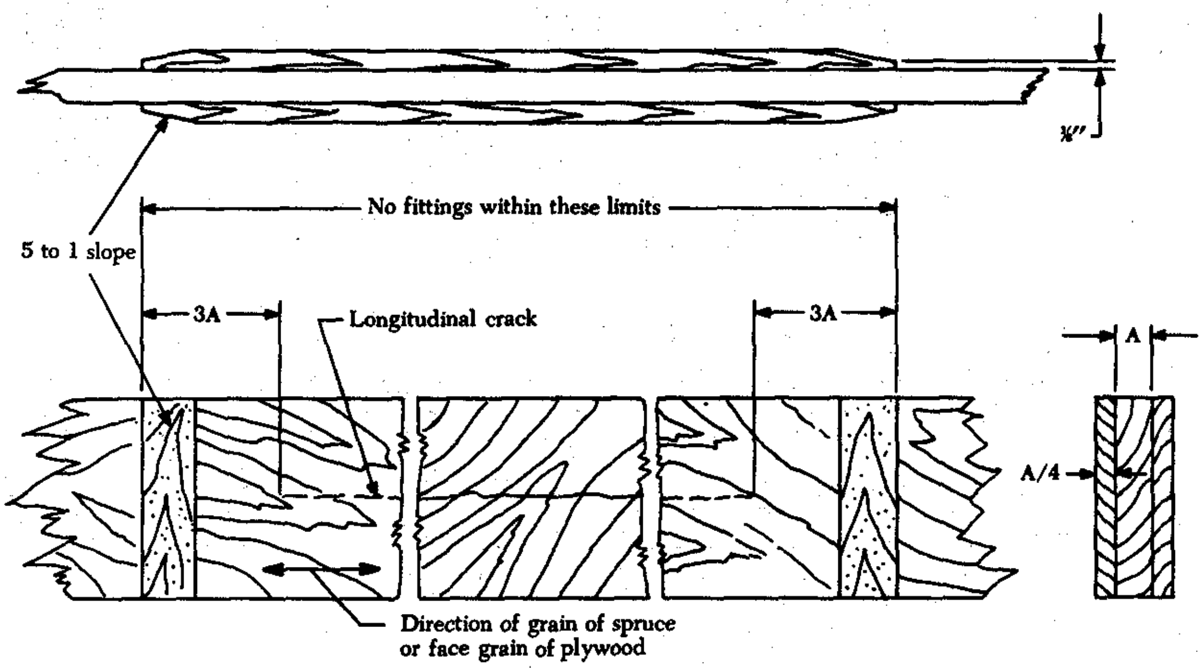
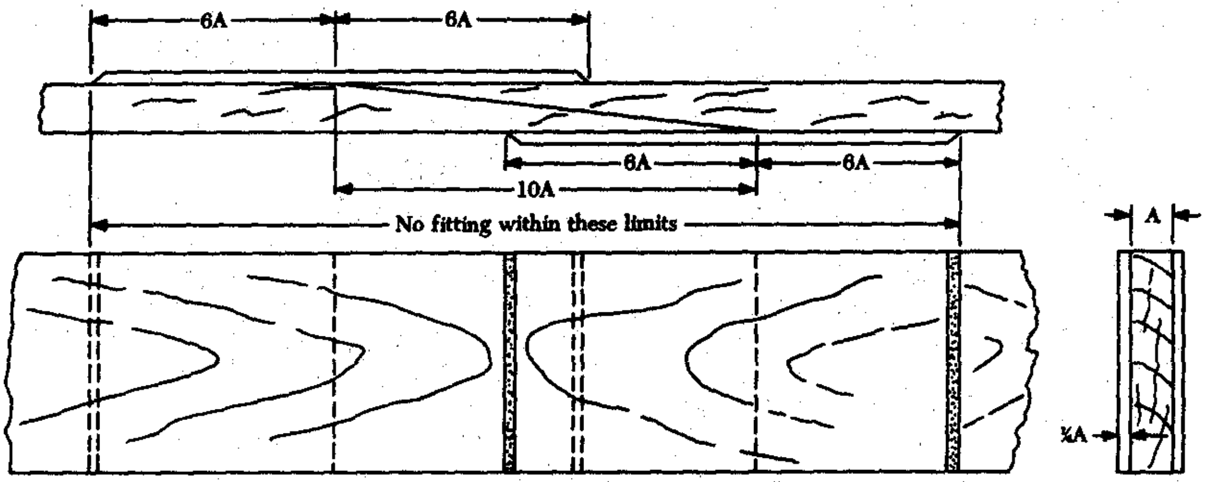


FIGURE 5-120. Reinforcing a longitudinal crack in a solid or internally routed spar.

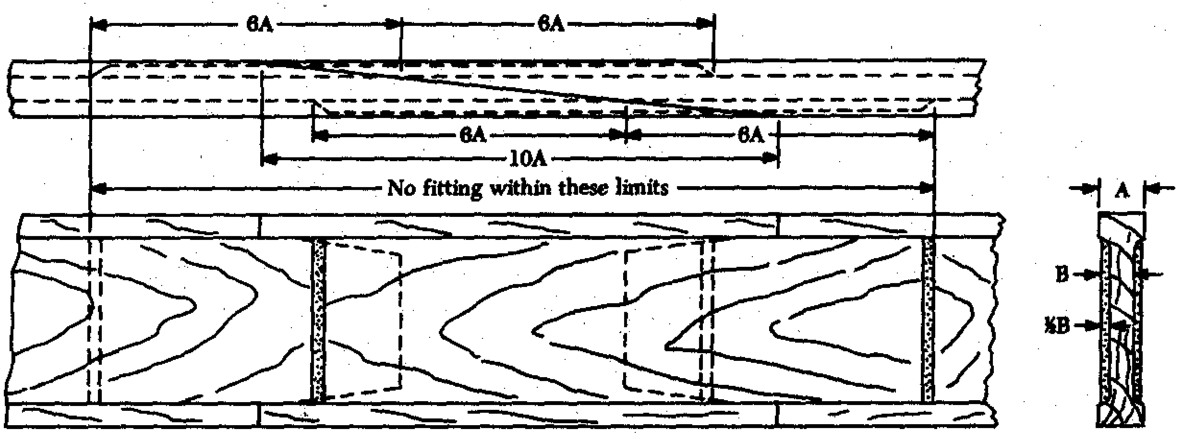
strut fittings is acceptable under the following conditions:

(1) The reinforcement plates of the splice should not interfere with the proper attachment or alignment of the fittings. The locations of pulley support brackets, bellcrank support brackets, or control surface support brackets should not be altered.

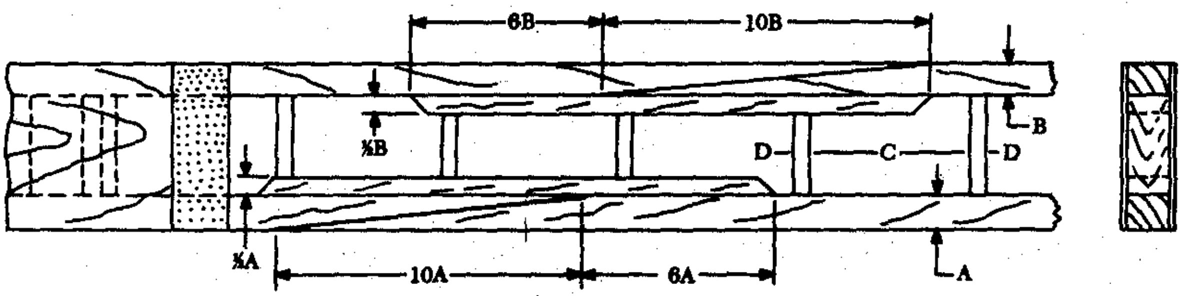
(2) The reinforcement plate may overlap drag or antidrag wire or compression strut fittings if the reinforcement plates are on the front-face of the front spar or on the



SPLICING OF SOLID RECTANGULAR SPAR



SPLICING OF SOLID ROUTED SPAR



SPLICING OF BOX SPAR FLANGES

FIGURE 5-121. Spar splicing.

rear-face of the rear spar. In such cases it will be necessary to install slightly longer bolts. The inside reinforcement plate should not overlap drag strut fittings, unless such overlapping does not require sufficient shortening of compression struts or changes in drag-truss geometry to prevent adjustment for proper rigging. Even though takeup is sufficient, it may be necessary to change the angles on the fittings. Space the splices so that they do not overlap. Reinforcement plates must be used as indicated on all scarf repairs to spars. The desired slope for the scarf is 12 to 1, but a slope of not less than 10 to 1 is acceptable. The plates are held in place by glue and must not be nailed.

Figure 5–121 illustrates the general method for splicing common types of wooden spars.

Always splice and reinforce plywood webs with the same type of plywood as the original. Do not use solid wood to replace plywood webs. Plywood is stronger in shear than solid wood of the same thickness because of the variation in grain direction of the individual plies. The face-grain of plywood replacement webs and reinforcement plates must be in the same direction as that of the original member to ensure that the new web will have the required strength. One method of splicing plywood webs is shown in figure 5–122.

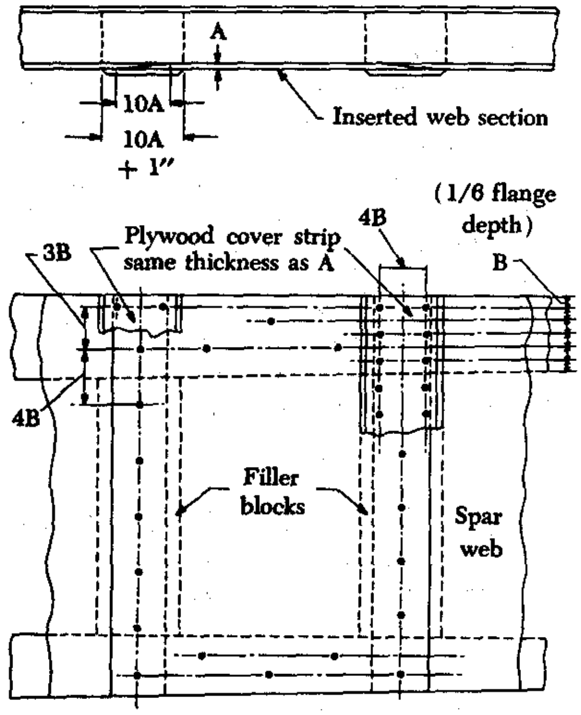


FIGURE 5–122. Method of splicing a box-spar web.

BOLT AND BUSHING HOLES

All bolts and bushings used in aircraft structures must fit snugly into the holes. Looseness allows the bolt or fitting to work back and forth, enlarging the hole. In cases of elongated bolt holes in a spar or cracks in the vicinity of bolt holes, splice in a new section of spar, or replace the spar entirely.

Holes drilled to receive bolts should be of such size that the bolt can be inserted by light tapping with a wood or rawhide mallet. If the hole is so tight that heavy blows are necessary to insert the bolt, deformation of the wood may cause splitting or unequal load distribution.

Rough holes are often caused by using dull bits or trying to bore too rapidly. Well-sharpened twist drills produce smooth holes in both solid wood and plywood. The twist drill should be sharpened to approximately a 60° angle. All holes bored for bolts which are to hold fittings in place should match exactly the hole in the fitting.

Bushings made of plastic or light metal provide additional bearing surface without any great increase in weight. Sometimes light steel bushings are used to prevent crushing the wood when bolts are tightened. The holes for bushings should be of such size that the bushing can be inserted by tapping lightly with a wood or rawhide mallet.

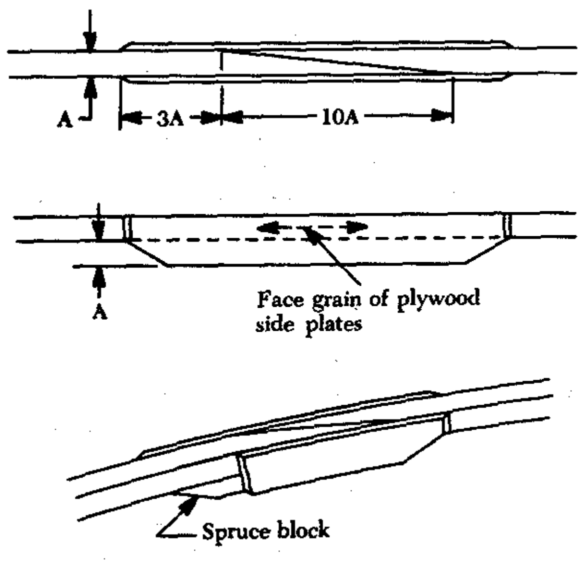


FIGURE 5–123. A rib cap-strip repair.

RIB REPAIRS

A cap strip of a wood rib can be repaired using a scarf splice. The repair is reinforced on the side opposite the wing covering by a spruce block which extends beyond the scarf joint not less than three times the thickness of the strips being repaired. The entire splice, including the reinforcing block, is reinforced on each side by a plywood side plate as shown in figure 5–123.

When the cap strip is to be repaired at a point where there is a joint between it and cross members of the rib, the repair is made by reinforcing the scarf joint with plywood gussets, as shown in figure 5–124.

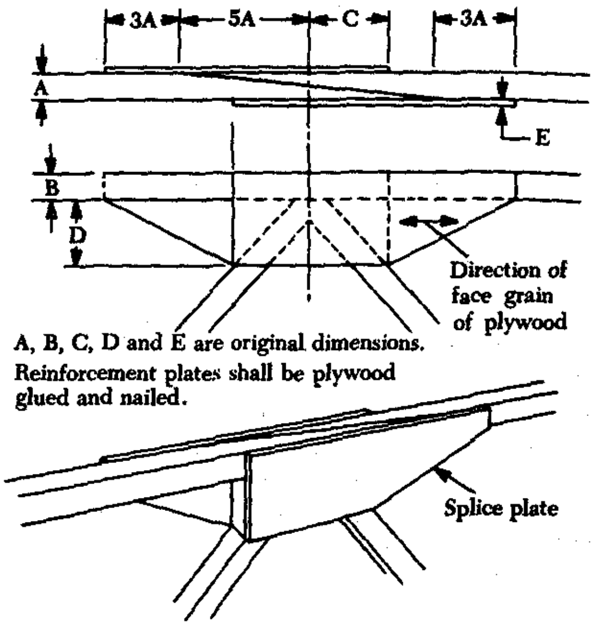


FIGURE 5–124. A rib repair at a joint.

When it is necessary to repair a cap strip at a spar, the joint should be reinforced by a continuous gusset entending over the spar as shown in figure 5–125.

Edge damage, cracks, or other local damage to a spar can be repaired by removing the damaged portion and gluing in a properly fitted block, as shown in figure 5–126, reinforcing the joint by means of plywood or spruce blocks glued into place.

The trailing edge of a rib can be replaced and repaired by removing the damaged portion of the cap strip and inserting a softwood block of white pine, spruce, or basswood. The entire repair is then reinforced with plywood gussets and nailed and glued as shown in figure 5–127.

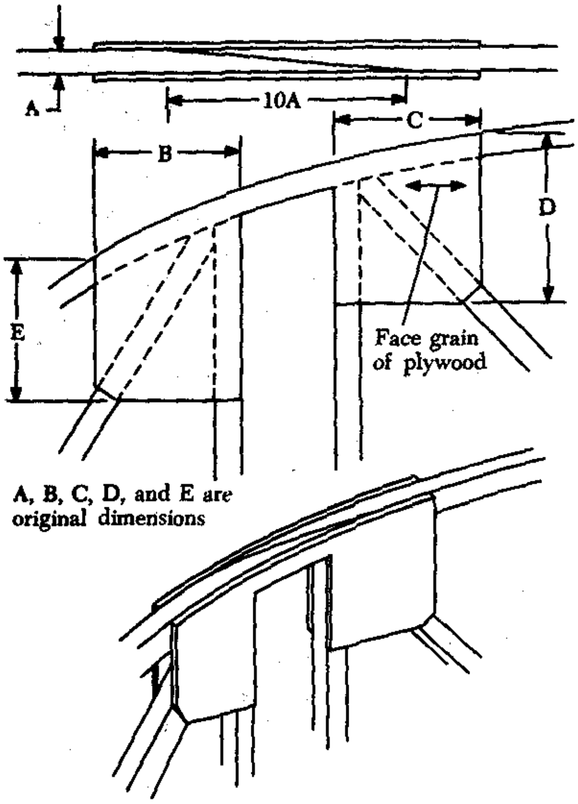


FIGURE 5–125. A rib repair at a spar.

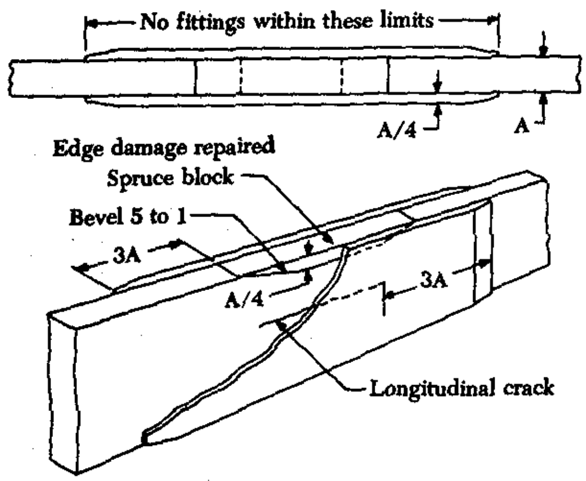


FIGURE 5–126. The repair of cracks and edge damage on a solid spar.

Compression ribs are of many different types, and the proper method of repairing any part of this type of rib is specified by the manufacturer. Figure 5–128 shows a typical repair made to a compression rib built up of a plywood web and three longitudinal members, the center one of which has been

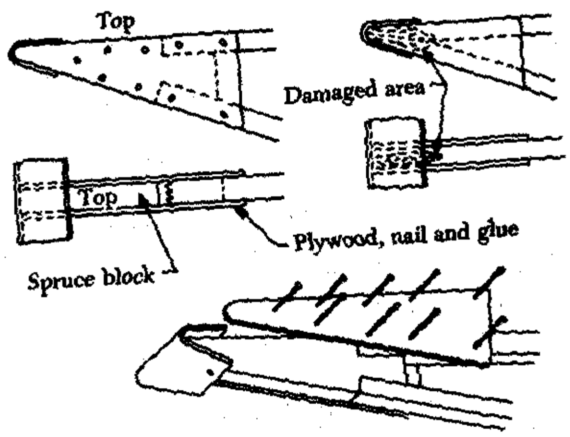


FIGURE 5-127. A rib trailing-edge repair.

repaired by a properly reinforced scarf joint and an outside layer of plywood.

Such members as glue blocks, filler blocks, compression members, braces, and rib diagonals should not be repaired, but should be replaced. Wherever it is possible to replace a damaged member, it is always better to do so than to attempt a repair.

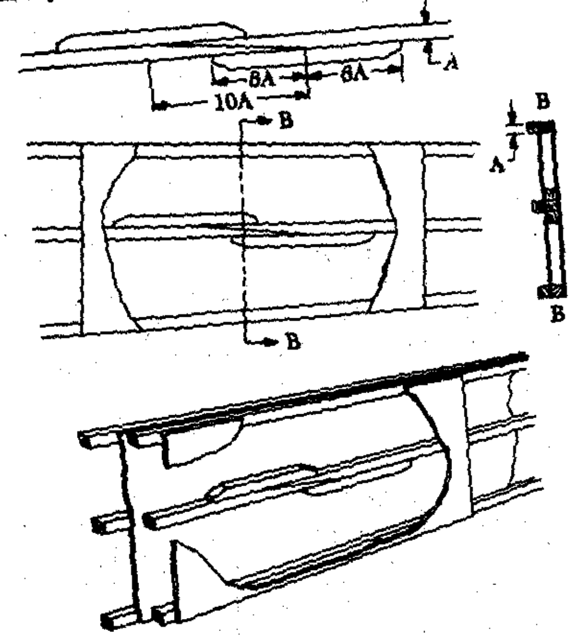


FIGURE 5-128. A compression-rib repair.